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AN ALTERNATIVE SEPTAGE TREATMENT METHOD: LIME STABILIZATION/SAND-BED DEWATERING

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AN ALTERNATIVE SEPTAGE TREATMENT METHOD:
LIME STABILIZATION/SAND-BED DEWATERING

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise, and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and

- a search for ways to prevent contamination and to recycle valuable resources.

Few desirable methods presently exist for the disposal of septic tank sludge. Septic tank pumpouts must nevertheless be treated safely and efficiently. This study provides one technically feasible and economically competitive alternative.

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ABSTRACT

Approximately 5 billion gal (18,927,000 m^3) of septage must be annually disposed of in the United States, a volume that is nearly equal to that of undigested raw and secondary municipal sludges. Few desirable methods exist for disposing of the sludge that is periodically pumped from septic tanks. This report describes the results obtained from a pilot study of one alternative septage treatment method-lime stabilization followed by covered sand-bed dewatering.

The study was conducted in two phases. Phase I (4 months) consisted of the general, chemical, and biological characterizations of the incoming septage. Attempts were made to thicken the material via stirring, polyelectrolyte addition, and lime addition. Phase II (9 months) concerned itself with the application of limed septage onto covered sand beds. Four experimental runs were conducted to assess the feasibility of such an approach. The septage was limed to pH 10.5, 11.0, and 11.5 and applied at 8-in. (20.3-cm) depths. Underdrainage and cake characteristics were monitored and practical sand-bed application rates were determined. A materials balance of chemical constituents around the system was made.

A cost estimate for the treatment of septage at small treatment plants via this method is included.

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ACKNOWLEDGMENTS

The authors express their appreciation to the Waste Identification and Analysis Section, Wastewater Research Division, MERL-Cincinnati for the analytical work, and in particular, to Bernard Kenner for the microbiological analyses. Albert Oberschlake and George Morrison of the Lebanon Pilot Plant also deserve special recognition for their contributions to the study.

INTRODUCTION

Many households depend on individual waste treatment systems for wastewater disposal. In the United States, approximately 126 million persons are connected to central sewerage systems, and about 74 million persons are served by other disposal methods.[1] The most common of these methods is the septic tank soil absorption system. The septic tank provides sedimentation of raw wastewater solids that accumulate and undergo partial digestion in the anaerobic mode. After a period of generally from 2 to 5 years, the tank must be pumped of collected floatable (scum) and settleable (sludge) solids. This step is necessary to prevent serious damage to the soil absorption system. A common procedure is for a septic tank hauler to pump the tank contents (septage) into a truck and to discharge the material at wastewater treatment plants that accept such wastes. In some cases, disposal of septage to municipal facilities is permitted. In many cases, however, treatment plants do not allow septage disposal because of possible detrimental effects on plant efficiency and pump clogging effects. As a result, unsafe and illegal disposal of these wastes to streams and to the land frequently occurs. For example, one frequently cited practice has been the disposal of pumpings to open pits, which pose health and safety hazards.[2]

Septic tank pumpouts must be treated and disposed of safely and efficiently. The easiest disposal method is to discharge septage at controlled rates to large-capacity waste treatment facilities where dilution with the incoming sewage is available. However, in areas where numerous individual home systems exist, the municipal treatment facilities most readily available are usually of a relatively small capacity. Small plants generally operate under conditions of highly variable flow and frequent hydraulic surges. Peak flows usually occur during the daylight hours, the same time period when septage dumpings are usually permitted. Unless some form of receiving station is available at the plant to permit holding the septage and releasing it to the plant in a controlled manner, the likelihood of upsetting the plant is greatly increased. As a result, many of the smaller plants refuse to accept these discharges, and truckers are often forced to find other dumping locations. Other alternatives for treating these wastes must be investigated and adopted to prevent the haphazard and dangerous release of these discharges to the environment.

LITERATURE REVIEW

Limited background information is available regarding the treatment and disposal of septic tank pumpouts. Kolega et al.[2,3,4] have described land applications of septage and characterized the material biologically and chemically. Smith and Wilson[5] have discussed the design of septage receiving facilities at treatment plants with emphasis on the importance of properly handling these discharges. Jewell et al.[6] have investigated the dewatering rates of septic tank sludge after aerobic and anaerobic digestion and after sand-bed dewatering. A description of a commercially available system for septage treatment also appears in the literature.[7] This process utilizes chlorine oxidation under pressure, with the end product being dewatered on sand beds or other dewatering devices. The use of lime as an effective bactericidal agent is well documented. Buzzell and Sawyer[8] added lime to raw wastewater and found that a pH of 10.9 initially killed all of the coliform bacteria. A study of lime disinfection of raw sewage at low temperatures showed that significant bacterial kill was achieved.[9] Lime stabilization of sewage sludges was investigated by Farrell et al.[10] and more recently by Battelle Northwest Laboratories.[11] The disposal and recycling of lime-containing wastewater sludges has been discussed by Dean and Smith.[12] A very recent report concerns itself with the septage problem in Norway.[13]

Computer searches were also made, but no information relating to methods of treating septic tank pumpouts was found. The following data bases were used: Lehigh University, Medline, Civil Engineering, Chemical Abstracts, and Engineering Index. A request to the Water Resources Scientific Information Center (WRSIC) resulted in more than 100 references, but were concerned with treatment of household wastes via septic tanks and not with the problem of sludge disposal.

DESCRIPTION OF THE STUDY

OBJECTIVES

The objective of this study was to examine some alternative treatment possibilities for septic tank pumpings. One major treatment alternative, lime stabilization followed by sand-bed dewatering, is described in this report. The terms "pumpout," "dumpings," "pumpings," and "septage" are all used throughout the paper to denote the material pumped from septic tanks. During the course of this study, several related tasks were carried out:

1. To define the nature and frequency of septic tank dumpings.
2. To characterize the general, chemical, and biological makeup of the septage.
3. To determine optimum pH conditions for effective lime stabilization.
4. To determine practical sand-bed application rates for limed septage.
5. To determine the fate of chemical and biological pollutants.

APPROACH

Before any pilot scale investigations were made, it was necessary to characterize the incoming material (Phase I). Thus, the initial 2 months of the study were spent collecting and analyzing septage received at the Lebanon, Ohio, Municipal Sewage Treatment Plant from local haulers. The following 2 months were used in attempts to thicken the septage. Jar tests were conducted to evaluate the effects of stirring, polyelectrolyte addition, and lime addition. Results obtained from 4 months of bench testing provided the basis for deciding to study the lime stabilization and sand-drying-bed treatment sequence (Phase II). Sand-bed dewatering of lime-treated septage was then investigated for 9 months. The first 6 months were devoted to assessing the effects of liming raw septage to three different initial pH levels before applying it to sand drying beds. The septage for stabilization was limed to pH 10.5, 11.0, and 11.5 and discharged to a covered bed sectioned off to accommodate each batch. Four experimental runs were conducted during this period to determine the feasibility of such an approach. Eight-in. (20.3-cm) application depths of the septage were made during these runs. Drainage and cake characteristics were monitored during three of the runs. The final 2 months were spent varying bed application rates to determine the maximum practical level. Limed septage depths introduced onto the sand beds were 8, 12, 16, and 24 in. (20.3, 30.5, 40.6, and 60.9 cm). Drying bed performance evaluation was based on dewaterability and ease of cake removal. Attempts were made to obtain a materials balance of chemical constituents around the system.

STUDY SITE

The study was conducted at the Lebanon Pilot Plant, Lebanon, Ohio. This facility is operated by the U. S. Environmental Protection Agency, Municipal Environmental Research Laboratory (MERL)-Cincinnati, Wastewater Research Division, and is situated adjacent to the Lebanon Municipal Sewage Treatment Plant (LMSTP), which is a 1.15 mgd (4370 m^3/day) activated sludge plant.

DUMPING PROCEDURE

The procedure required by LMSTP for all septic tank haulers is to discharge 1,000-to 2,000-gal (3.8-to 7.6-m^3) loads of septage into the main interceptor line located upstream from the comminutor. Other requirements imposed by the City of Lebanon are:

1. Dumping is allowed at the LMSTP on weekdays between the hours of 7:30 AM and 4:30 PM only.
2. An attendant of the LMSTP must be on the site at the time of dumping.
3. Haulers must show a valid license or permit issued by the Board of Health.
4. Septage being dumped cannot contain any waste oil, kerosene, gasoline, cleaning compound, or other substance obviously harmful to plant operation.
5. Septage containing industrial wastes is not accepted.
6. Dumping fee is $5.00 per tank load up to 1,000-gal (3.8-m^3) tank capacity and $10.00 per tank load for larger capacities.

An important part of the study was having the cooperation of the septic tank haulers. At the beginning, there were three septic tank services that regularly discharged septage at the LMSTP. The septage consisted of household, school, and machine shop wastes. The latter contribution was disallowed after a time because of its oily nature and detrimental effect on plant operation. Sometimes a hauler had to be called on to deliver septage needed for the study as the winter months approached and discharges to the plant decreased.

EQUIPMENT REQUIREMENTS

Phase I

During the bench-testing phase, little hardware was required. All thickening runs took place in graduated cylinders: initially, 1-liter cylinders, and later, 2-liter cylinders for jar tests with lime and polymers. Two- and 4-rpm stirrer-equipped motors adapted with shafts and wires to fit comfortably into the cylinders were used to evaluate stirring effects.

Phase II

Figure 1 shows the set-up used for the pilot phase. The lime slurry tank consisted of a 1,750-rpm mixer fastened to the inside of a 30 gal (114-liter) drum. The 25-percent-by-weight lime ($Ca(OH)_2$) slurry was bucketed from the drum and introduced into the holding tank, which was previously filled with septage. The 4,500-gal (17-m^3) tank was located outdoors and above ground and modified to accept septage as directly pumped or gravity-fed from the truck. The cylindrically shaped diffusers, each about 15 in. (38 cm) long, were radially positioned 120° apart on the floor of the tank to air mix the lime with the septage. When the desired pH level was reached, the mixture was allowed to flow by gravity through approximately 100 ft (30.5 m) of 4-in. (10.2 cm) diameter flexible pipe to the covered sand bed. Figure 2 shows a sectional view of the modified drying bed and the cover over it. The bed was quartered off, with 64 ft^2 (5.8 m^2) of useable area available in each section. The wood planking used was creosote-treated to minimize attack by the lime. Heavy-duty plastic was draped over the planks to prevent cross-septage of the waste. The access doors, located on either side of the roof, served as entrances to the bed. At the end of each test period, the septage cake was removed through these doors. Because it was not possible to collect drainage separately from each of the bed sections, three simulated sand beds were constructed from cylindrical fiberglass drums 2 ft (0.6 m) in diameter x 4 ft (1.2 m) deep, and each was equipped with a bottom sample tap. The drums were also located in a section of the covered structure and filled with 12 in. (30.5 cm) of sand, 15 in. (38.1 cm) of #6 gravel, and 3 in. (7.6 cm) of #3 gravel (the same as the beds). Each time limed septage was applied to a section of the big beds, a corresponding depth was applied to one of the drums. In this way, the drainage from all sections was monitored.

SAMPLING AND ANALYSIS

The sampling schedule for both phases of the study is outlined in Table 1.

Phase I

Samples for the characterization phase were taken directly from the discharge line of the truck at the point before entering the manhole. Grab samples were taken in 2 1/2-gal (9.0-liter) buckets near the beginning, middle, and end of the approximately 20-min unloading time and composited in a fourth bucket. Samples from 21 sources of domestic septage and five machine shop loads were analyzed. Two-hr and 4-hr settleability tests were run, with and without stirring, with lime addition, and with polyelectrolyte addition.

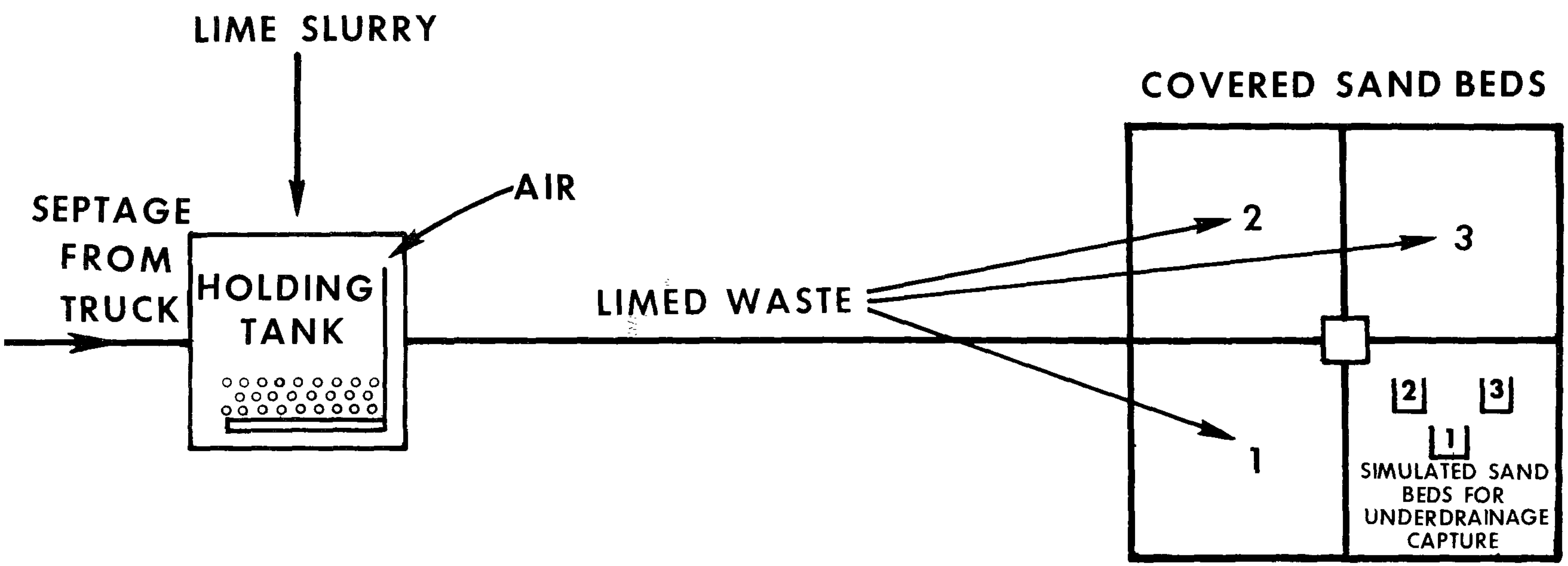

Figure 1. PILOT STUDY FACILITIES

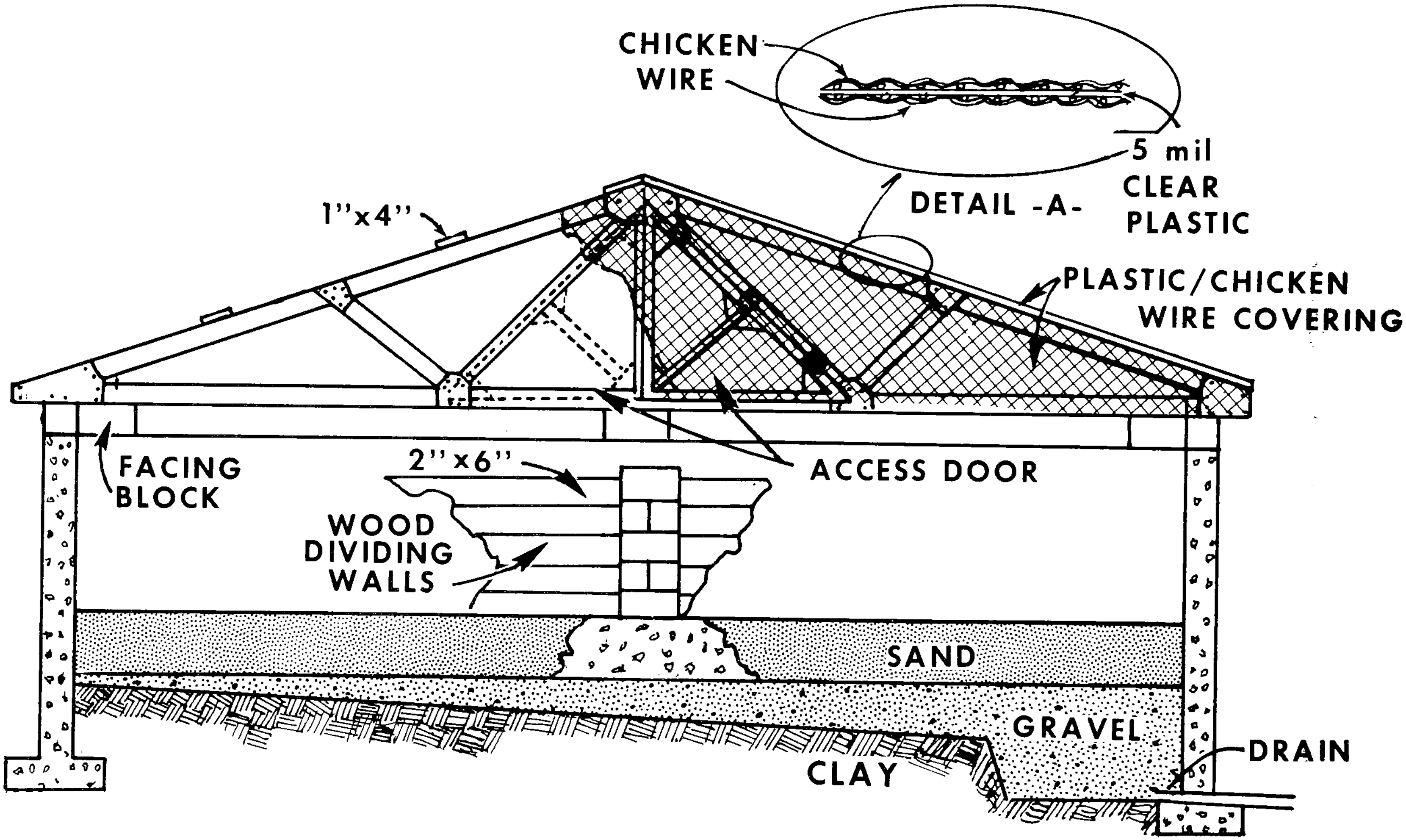

Figure 2. COVERED SAND BED CONSTRUCTION

Table 1.
SAMPLING SCHEDULE

	Phase I - Characterization	Phase II - Pilot		
		Daily	Twice Weekly	Three Times Weekly
pH	X	X		
Total Solids (%)	X	X		
Total Volatile Solids (%)	X	X		
COD	X			X
TOC				X
N_2 Series	X			X
Total Hydrolyzable Phosphorus	X			
Hexane Extractable Materials	X			X
Heavy Metals (iron, manganese, cadmium, nickel, and mercury)	X			
Settleability Tests	X			
Bacterial Analyses			X	
Covered Bed Temperature		X		
Relative Humidity		X		

Phase II

Samples for the pilot study were taken from the holding tank after the contents of two or three haulers were allowed to mix for about 1-hr. A part of the sample was poured into a beaker and used to estimate the amount of lime necessary to attain the desired pH level in the tank. A few gallons less than the volume of lime slurry extrapolated from the bench determination were added to the holding tank and allowed to mix for about 20 min before pH was measured. This procedure was repeated until the required pH was reached. Samples of the limed waste were taken from the discharge line entering the sand bed. Subsequent representative samples of the limed septage during each test period were taken from the respective 64-ft^2 (5.8-m^2) section of the bed by withdrawing samples from five places in the section and compositing them. Drainage from each drum was collected for chemical and bacterial analysis and, in later runs, drainage volumes were also recorded so that material balances could be made.

All chemical and most bacteriological procedures were carried out in accordance with the methods described in *Standard Methods*.[14] Bacteriological methods for the determination of *Salmonella* species and *Pseudomonas aeruginosa* were developed by Kenner.[15]

RESULTS

PHASE I - SEPTAGE CHARACTERIZATION

Quantity Discharged

The results reported here reflect data accumulated from July 1972 to September 1973. To quantify the extent to which septage was discharged at the Lebanon site, a record was kept of the total volume unloaded each month during 1972 and during the first few months of 1973 (Figure 3). As the figure shows, most septic tanks are pumped during the warmer months. From April to September, 550,000 gal (2,082 m^3), or about 75 percent of the total 1972 volume of septage, was discharged to the treatment plant. The total accountable quantity of septic tank wastes during 1972 was 717,000 gal (2,725 m^3), and the average plant flow was 1.4 mgd (5,320 m^3/day). Assuming that 45 percent (230 million gal or 874,000 m^3) of the yearly plant flow entered the plant between 7:30 AM and 4:30 PM (allowable interval for haulers to dump their loads), approximately 0.3 percent by volume of the plant intake was septic tank waste (assuming all of it entered the plant). Unfortunately, septage discharges are intermittent and constitute a greater instantaneous portion of the total flow at the time of discharge. At an average plant flow (7:30 AM to 4:30 PM) of 975 gpm, assuming that a hauler dumps a 1,000 gal load in 15 min, the septage to sewage volume ratio ($Q_{septage}/Q_{sewage}$) would be approximately 0.07 or 7 percent of the total influent flow. The result is a temporary overload and possible upset of the plant.

Physical and Chemical Characterization

Results of the characterization phase are shown in Table 2. The data were divided into two groups: domestic wastes (average pH 6.9) and machine shop wastes (cutting oil) (average pH 9.6). The color of the domestic septage varied from black to brownish-black, or gray, and the color of the oil was cream. Odors were similar to those of sewage for the household wastes and similar to kerosene for the cutting oil. Although these two types of wastes were distinctly different in source and appearance, there was a surprising similarity in content. It is unknown whether the presence of heavy metals in the domestic septage originated in the septic tank or resulted from previous truckloads.

Settling characteristics of the septic tank wastes were very erratic. Samples were examined at 15-min intervals in 1-liter graduated cylinders to determine settleability. The cutting oil waste did not settle at all. Before the first domestic sample settled, 25 consecutive samples had not.

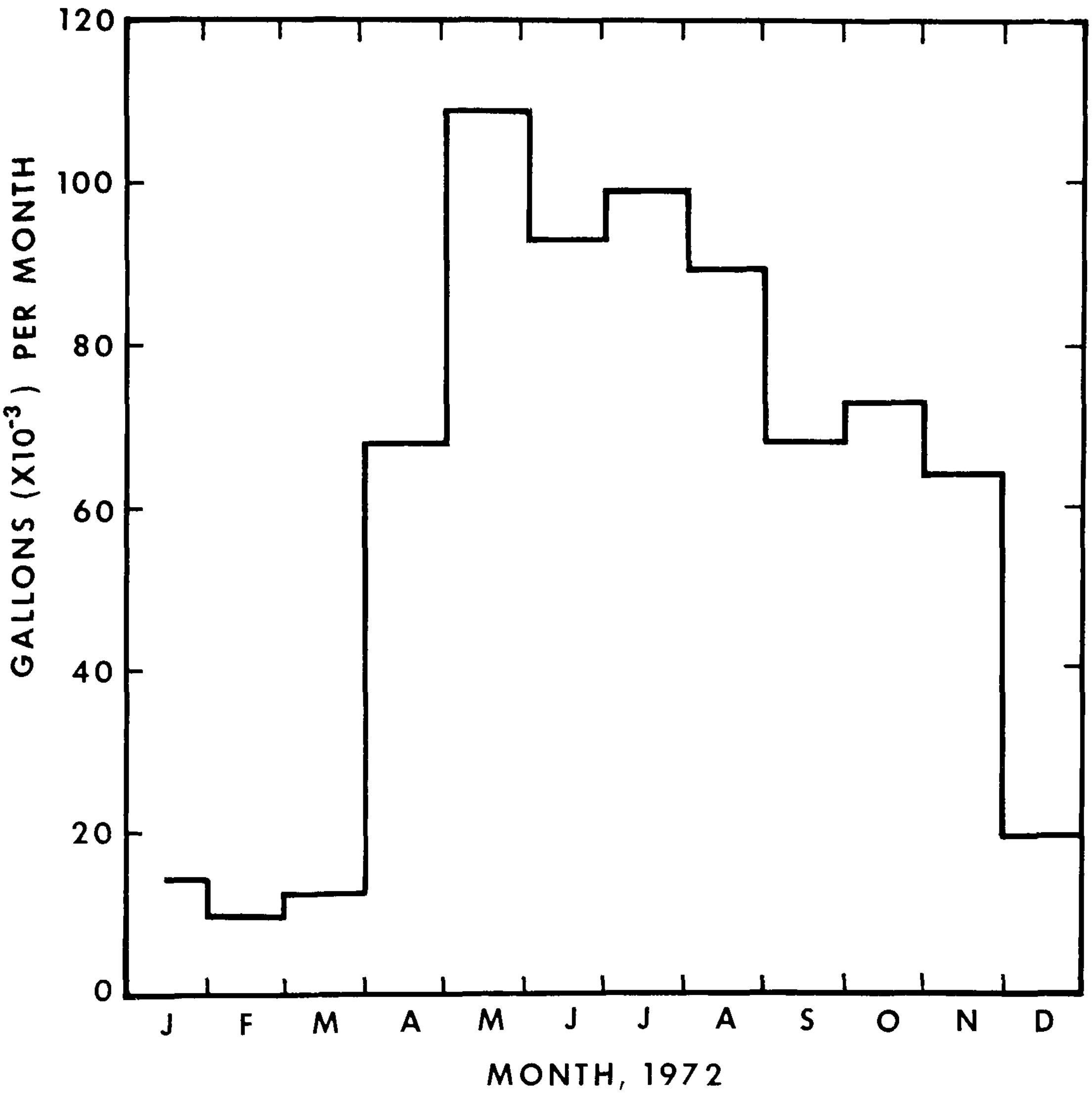

Figure 3. SEPTAGE LOADING PATTERN AT LEBANON

Table 2.
CHARACTERIZATION OF SEPTIC TANK WASTES LEBANON, OHIO*

Parameter (mg/l)	Domestic Waste (21 Samples)	Machine Shop Waste (5 Samples)
pH	6.9	9.6
Total Solids (%)	3.95	4.14
Range	0.68 - 10.6	2.57 - 10.0
Volatile Solids (%)	69.3	54.3
Total COD	60,582	63,750
Hexane Extractable Materials	9,561	10,377
Total Kjeldahl Nitrogen	650	446
NH_3 - N	120	143
NO_2 - N	1.3	0.8
NO_3 - N	1.2	1.7
Tot. P	214	107
Fe	163	103
Mn	5.4	3.6
Zn	62	89
Cd	0.2	--
Ni	<1.0	<1.0
Hg	0.022	0.043

*In mg/l unless otherwise noted.

A settling curve for the 26th sample is represented by the control line of Figure 4. The figure shows that approximately 15 percent settling occurred after 2 hr, 25 percent after 4 hr, and only 46 percent after 24 hr. The term "percent settling" is defined as the ratio of the graduated cylinder interface height difference (in ml) between the beginning and ending settling points divided by the interface height beginning point multiplied by 100. Results from two other occasions when some natural settling took place are shown in Figure 5 and 6; they also indicate relatively poor settling (10 and 40 percent after 2 hr).

Because minimal thickening took place, attempts were made to bring about liquid-solid separation of the septage via stirring. Stirring tests at rates of 2 rpm and 4 rpm showed that in cases where no thickening occurred, stirring did not help; but when some thickening was possible, it was promoted by stirring. The curves in Figures 4 through 6 show the positive results of stirring. Stirring speed apparently did not effect the thickening rate.

Despite the benefits of stirring, additional thickening was considered mandatory for good separation, and the use of lime and polyelectrolytes was next investigated. No further research was done with the cutting oils, and in fact, their discharge to the Lebanon Plant was no longer permitted after November 1972.

Jar Tests

Jar tests with lime were conducted in the following way: Based on the total soilds content of the septage, dosages of 5 to 20 percent lime were made. The lime was introduced into 2-liter graduated cylinders in a 25-percent slurry. Figure 7 shows the results of one of these tests and is typical of other test results. A maximum of only 38 percent thickening occurred after 2 hr and 50 percent after 4 hr with lime addition. Stirring of the limed samples showed increased settling over the unstirred limed samples, but still a maximum of only 50 percent thickening was achieved.

Six cationic polyelectrolytes* (Calgon 2600, 2640, and 2660; Purifloc C31 and C41; and Ionic NC721) were used in the jar tests, as well as three anionic polymers (Calgon 2690A, Magnifloc 835A, and Magnifloc 837A). Total solids concentrations of the tested septage ranged from 0.8 to 4.6 percent. Standard jar test procedure was to introduce each polymer at a dosage of 10 milligrams of polymer per gram of sludge solids. Samples were allowed to settle in the graduated cylinders for 2 hr, with readings taken at 15-min intervals. Results were inconsistent. In two cases (sample total solids concentrations of 4.6 and 3.6 percent), virtually no thickening took place with any of the polymers even after 4 hr of settling. When the polymer dosages were doubled to 20 mg per g of dry sludge solids for samples containing 3.6 percent solids, the sample with cationic polymer C2600 resulted in 23 percent settling after 1 hr. An equivalent amount of settling resulted after 1 hr with stirring (2 rpm) plus 10 mg C2600 per g

*Mention of a proprietary product does not constitute an endorsement or recommendation by the Federal Government.

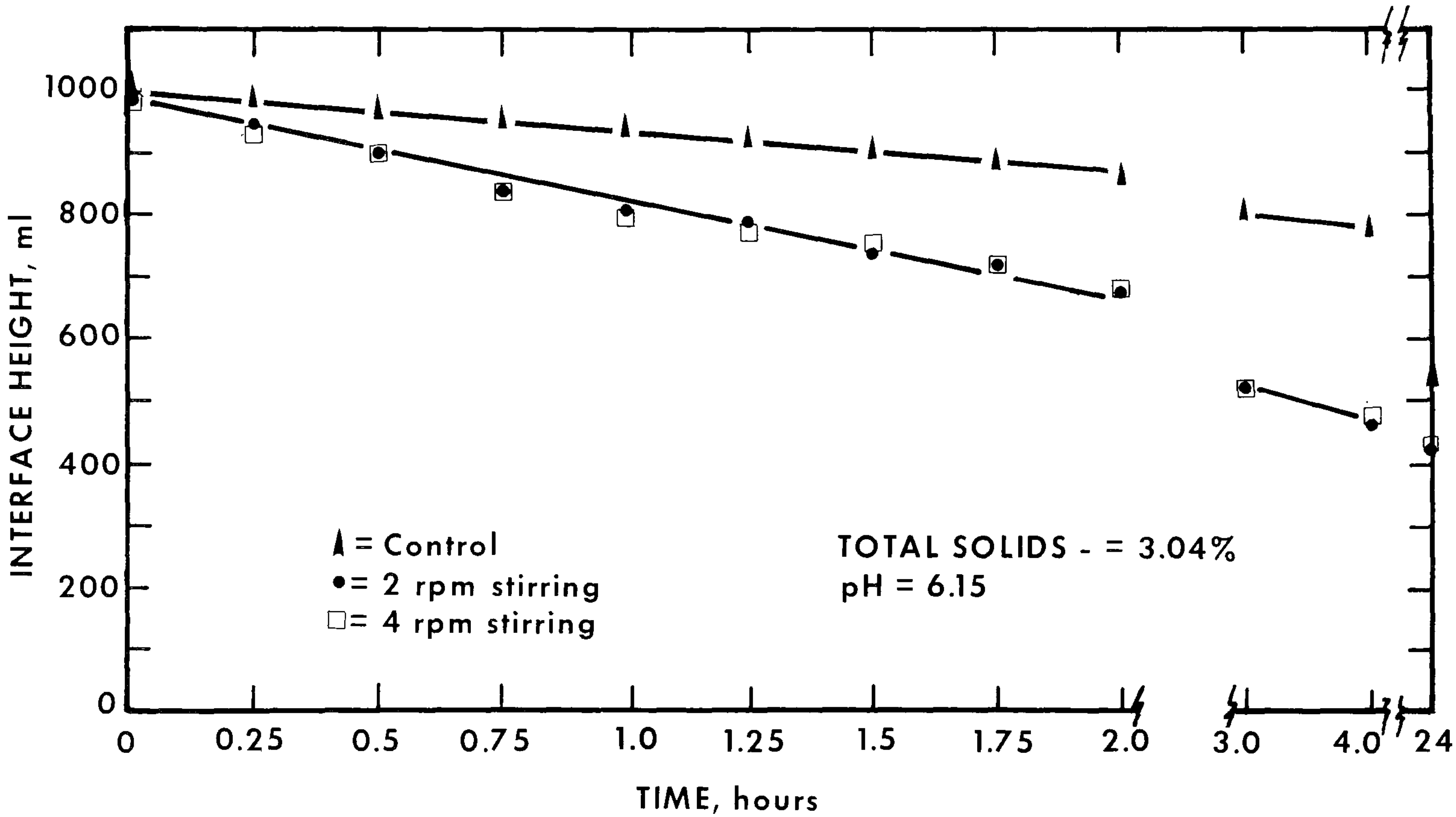

Figure 4. EFFECT OF STIRRING ON SEPTIC TANK WASTE THICKENING

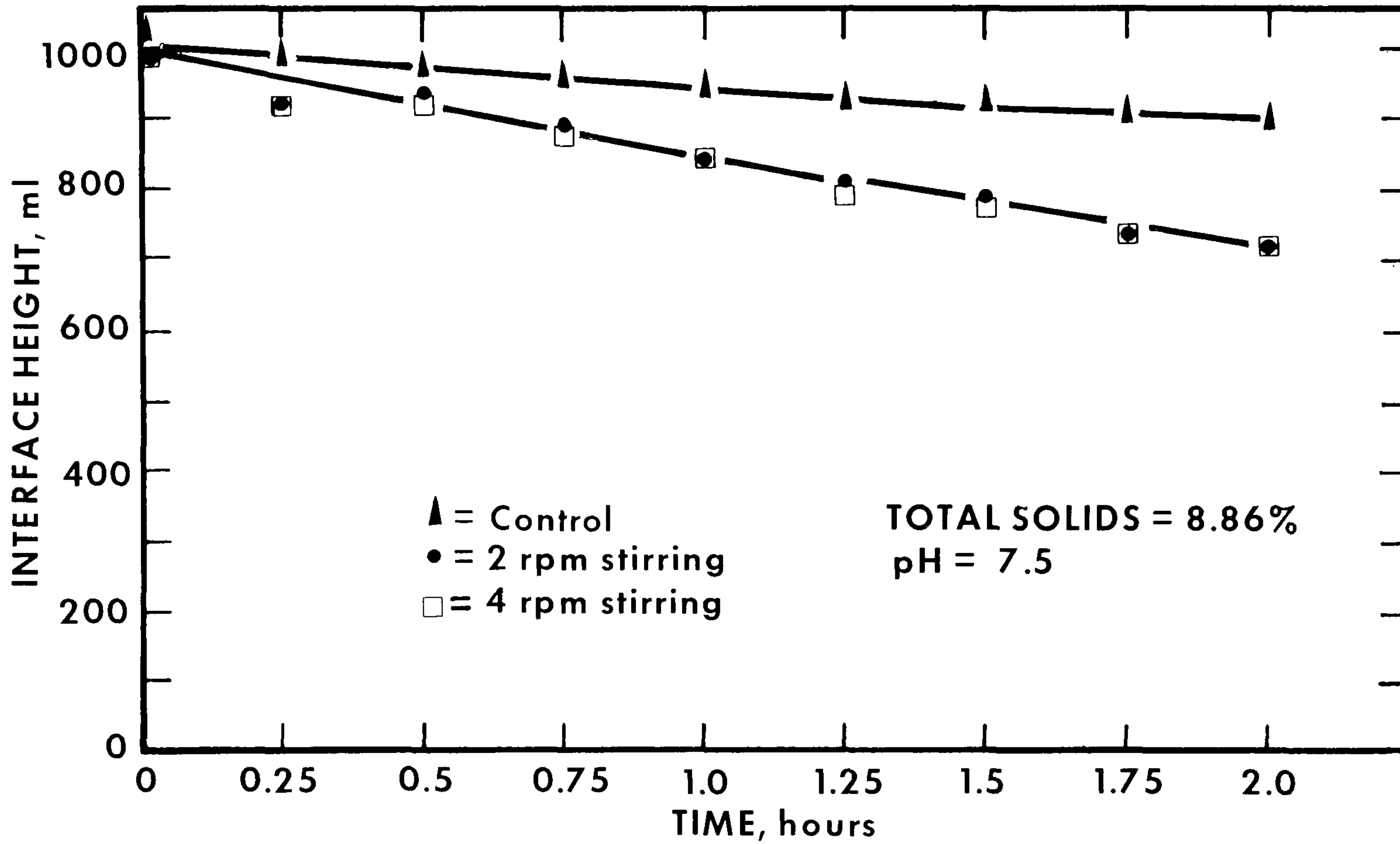

Figure 5. EFFECT OF STIRRING ON SEPTIC TANK WASTE THICKENING

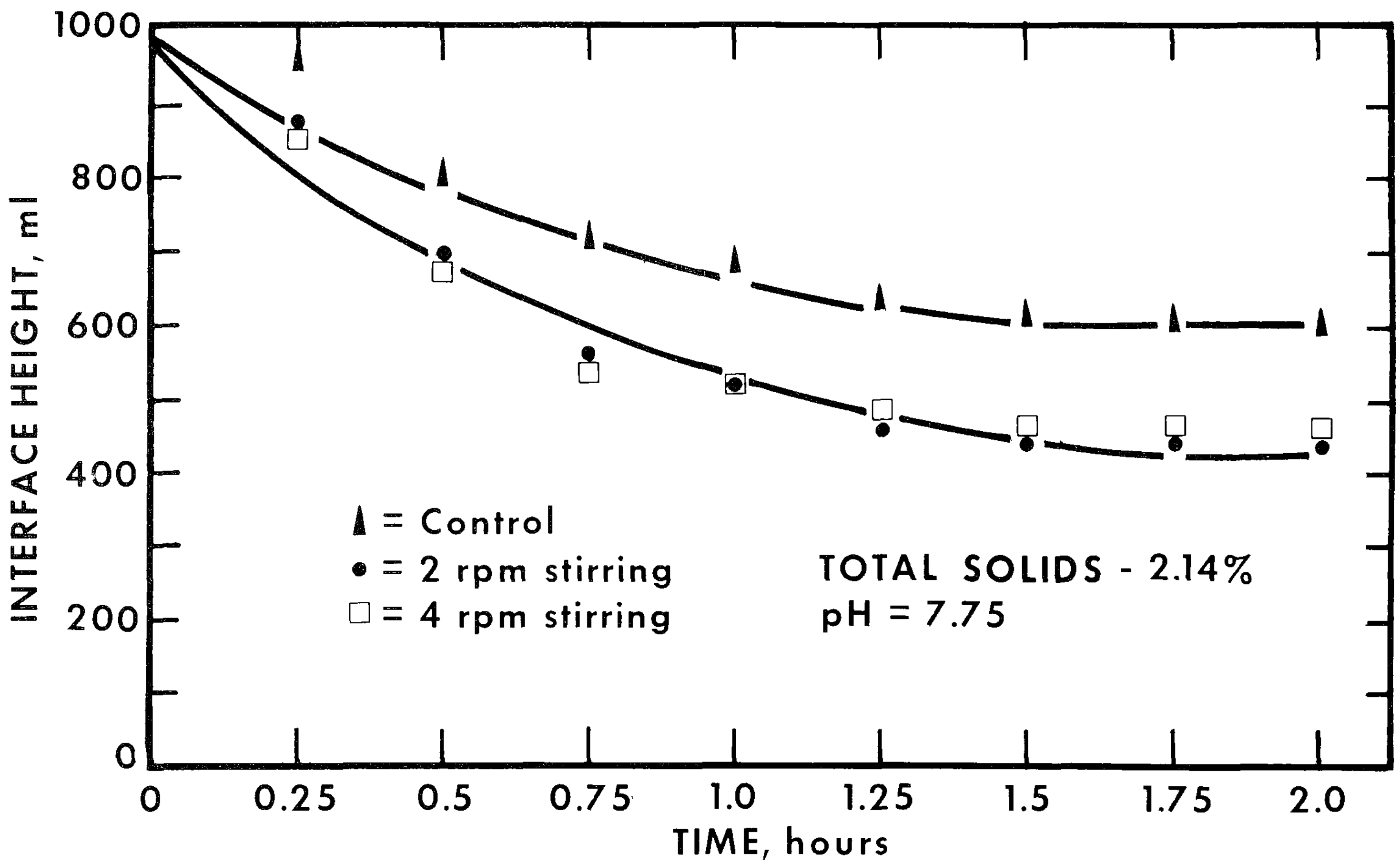

Figure 6. EFFECT OF STIRRING ON SEPTIC TANK WASTE THICKENING

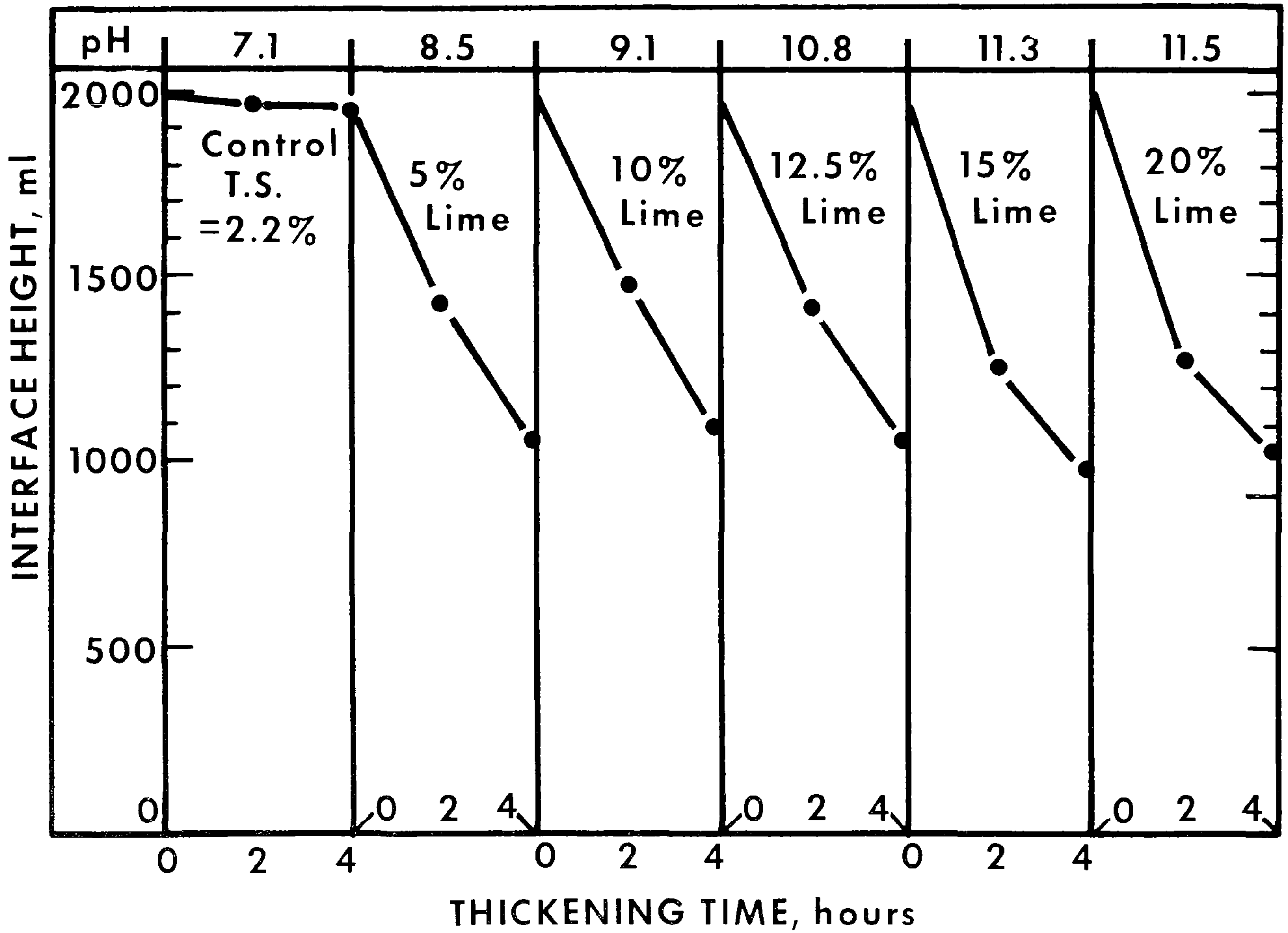

Figure 7. EFFECT OF LIME ADDITION ON THICKENING

of solids, indicating that stirring may reduce the amount of polyelectrolyte required to accomplish equivalent amounts of thickening. In two other cases, the C2600 polymer resulted in almost 75 percent settling without stirring and almost 85 percent with stirring. Tests with a range of dosages (2-15 mg C2600 per g of solids) showed that the use of 2 mg per g effectively resulted in as much settling as with the higher dosages, although the clarity of the supernatant was not as good. The anionic polymer C2690A was the next most effective polymer. The other anionic polymers brought about virtually no settling.

The importance of good separation is shown in Table 3, where the heavy metal distribution between phases is compared for septage samples with and without polymer addition. The use of polymer substantially increased the capture of materials in the underflow. The supernatant concentration values were obtained from supernatant samples decanted from the graduated cylinder and were directly analyzed, rather than first having been filtered. Table 3 also shows the distribution of other materials present in the untreated septage samples. Most of the COD and TOC and much of the phosphorus and Total Kjeldahl Nitrogen appeared in the solid phase.

Conclusions

Tests were conducted to determine whether septage would effectively separate into solid and liquid fractions for the purpose of treating each phase individually. Neither natural settling, lime addition, nor polyelectrolyte introduction resulted in consistent separation. Even though one polymer proved optimum most of the time, the thickening that resulted fluctuated from 25 to 75 percent. The separation approach was therefore considered technically unfeasible and impractical for implementation at the average sewage treatment plant. A decision was thus made that pilot plant investigations of septage treatment alternatives would involve only approaches where the septage is treated as a whole. Two avenues were considered: studying the effects on the biological treatment plant of discharging the material at controlled rates and treating the septage independently of the plant. The latter approach, utilizing lime stabilization followed by sand-bed dewatering, was chosen for several reasons: (1) total solids concentrations as great as 10 percent were present in the septage and would be kept out of the treatment plant, (2) heavy metal constituents could be complexed by the lime, (3) bacterial kills could potentially result from lime addition, (4) lime is a relatively low-cost chemical, (5) sand beds are available at many small treatment plants, (6) drainage from the sand beds should be of better quality than the septage, (7) if workable, the procedure could be easily implemented by sewage treatment plant personnel and, (8) if workable, the process may not have to be dependent on the presence of a sewage treatment plant.

PHASE II - PILOT STUDIES

Experimental Runs 1 through 4: Lime Stabilization

Run 1 -- Approximately 2,100 gal (8.0 m^3) of septage from two haulers were pumped into the holding tank, air-mixed, limed, and applied to the sand beds for further study. The air-mixing system provided adequate mixing, even though distribution was not equal among the three diffusers used. Other investigations have documented the advantages of air-mixing over mechanical mixing.[11]

The general, chemical, and biological characteristics of the raw septage tested are shown below:

General:

Color		dark brown
pH		6.5
Total solids	%	3.2
Total volatile solids	%	63.4

Biological:

	Counts/100 ml
Fecal coliforms	6.1×10^6
Fecal streptococci	1.8×10^6
Pseudomonas aeruginosa	6.0
Salmonella species	0.3

Chemical:

	mg/l
COD	41,500
TOC	11,200
TKN	816
NH_3-N	380
NO_2-N	<0.1
NO_3-N	<0.1
Total P	200
Fe	450

Chemical -- continued

	mg/l
Cu	0.3
Ni	0.7
Zn	52.0
Cr	0.6
Cd	0.2
Mn	4.4
Hg	0.154

Odors were initially present, but they improved with air-mixing and lime addition. The true ammonia and TKN concentrations were probably higher than those shown, because a portion of the ammonia was stripped during air-mixing. The contribution of heavy metals in the septage is important to note. Whether they were actually present in the septic tank or appeared as a result of cross-contamination in the tank truck was not apparent. In any event, septage treatment methods must consider the fate and effects of heavy metals.

The intended limed pH values for sand-bed dewatering studies were pH 10.5, 11.0, 11.5, and 12.0. Unfortunately, the pH 11.0 value was exceeded, and therefore limed septage was applied to three sections of the sand drying bed. Loading depth to each section (area, 64 ft^2 or 5.95 m^2) was 8 in. (20.3 cm), which corresponded to a volume of 320 gal (1.21 m^3). The actual pH values introduced onto the beds and the amounts of lime required to reach those values are tabulated as follows:

TABLE 3. SEPARATION EFFICIENCY AS A FUNCTION OF DEGREE OF SETTLING

	No Polymer (50% Settling)[a]			Polymer (70% Settling)[b]		
Parameter	Supernatant (mg/l)	Solid Phase (mg/l)	Solid Phase (%)	Supernatant (mg/l)	Solid Phase (mg/l)	Solid Phase (%)
Fe	30	215	88	1.3	850	99+
Mn	3.0	4.6	61	<0.1	26.6	99+
Cu	3.0	5.4	64	2.1	13.8	85
Zn	6.2	11.2	64	5.1	140	97
Cr	4.4	5.6	56	1.2	8.3	86
Cd	0.5	0.8	61	<0.1	0.4	-
Ni	3.0	4.0	55	<0.5	14.2	96+
Hg (μg/l)	.002	15.8	88	<0.2	44	99+
Total P	70	173	71			
Total COD	4,728	33,458	88			
Total TOC	1,910	8,460	82			
TKN	410	844	68			
NH_3-N	220	215	50			
NO_2-N	-	-	-			
NO_3-N	1.0	1.0	50			

[a] settling time 4 hours, untreated septage

[b] settling time 2 hours, 10 mg/g C2600 polymer added

Actual pH	Gal (liters) of 25% lime slurry required	lb (kg) of lime required	lb of lime/ton (kg/metric ton) of dry solids
10.4	12 (45)	25 (11.4)	92 (46)
11.6	20 (76)	41.6 (18.8)	180 (91)
12.0	21.8 (83)	45.2 (20.5)	240 (120)

After the first day on the beds, the pH of all wastes dropped 0.4 to 0.5 pH units. The nature of the samples taken showed that sampling techniques would become the most critical part of the study. Despite precautions taken to even out the sand level in each section of the bed, application of the waste resulted in uneven distribution in some places; floating solids were noticed, and in others, most of the solids had settled onto the sand. After the second day, only 1 1/2 in. (3.8 cm) of the original 8 in. of waste remained; yet only a slight increase, and in one case a decrease, in total solids concentration from the original 3.2 percent was measured. This result was undoubtedly an error in sampling and was alleviated beginning with Run 2 by sampling from several points within the same section, thus assuring that samples were as representative as possible. Although the sampling procedures used were not completely satisfactory, a general trend in the dewatering characteristics of each of the sludges was observed. After 6 days, the cakes all thickened to approximately 28 percent solids; after 19 days, all cakes dewatered to greater than 38 percent solids. The dewatering times were reasonably short compared to the times normally required for the sand bed drying of municipal sludges. It is further encouraging in that the ambient temperature and relative humidity in the enclosure averaged, respectively, 5°C and nearly 100 percent during the run. Volatile solids measurements remained about 63 percent for all pH levels. A decision was made to sample daily the total solids levels of future batches until concentrations of 20 to 30 percent were reached. At that time, the sludge cake could be hauled away and preparations made to receive a new load.

Run 1 served to point out sampling and operational problems to be expected during the study. The rapid drying times and ease of cake removal for each batch of limed septage were encouraging. The presence of heavy metals and the importance of tracing their paths were made evident. Also, pH levels could be expected to decrease as a function of time, regardless of initial pH. No intolerable odors in the bed enclosure were detected, however.

Run 2 -- After the septage was removed from the sand beds, new sand was added, and the three sections were raked evenly to receive the next batch. The holding tank was cleaned of residual septage, rags, grit, etc. from the previous experimental run.

Run 2 was conducted for 16 days, at which time the cake was considered truckable and was removed. General and chemical characteristics of the unlimed septage are as follows:

General:

Color		dark gray
pH		8.8
Total solids	%	3.1
Total volatile solids	%	63.0

Chemical:

	mg/l
COD	57,700
TOC	17,000
TKN	1,200
NH_3-N	380
Total P	24
Fe	222
Cu	8.8

Chemical -- continued

	mg/l
Ni	0.7
Zn	33.0
Cr	1.4
Cd	0.2
Mn	6.5
Hg	0.0035

Although the initial pH of the waste was abnormally high, all indications were that the source was domestic sewage and not cutting oil. The organic concentrations were significantly higher than in the previous batch, but the inorganic concentrations were generally lower. Total and volatile solids levels were the same, however.

The septage was limed to pH 10.4, 10.9, and 11.5 for discharge to the sand drying beds. The amounts of lime required are tabulated below:

Actual pH	Gal (liters) of 25% lime slurry required	lb (kg) of lime required	lb of lime/ton (kg/metric ton) of dry solids
10.4	19.5 (74)	40.6 (18.4)	131 (66)
10.9	21.5 (81)	44.8 (20.3)	167 (85)
11.5	24.0 (91)	50.0 (22.7)	219 (110)

As in Run 1, the pH of the waste in all sections decreased about 0.5 pH units after the first day and continued to decrease linearly throughout the remainder of the run. Regardless of initial pH, the final pH of the 16-day run was 8.5 to 8.7 for each limed waste. The underdrainage pH fell to a constant value of 8.2 within 2 to 4 days of application.

The dewatering trend for each bed during Run 2 appears in Figure 8. The original waste contained slightly greater than 3 percent total solids, and the lime addition increased the solids level to 4.5 percent. An interesting note is that the low-limed waste dried the quickest and the high-limed waste the slowest of the three batches. One explanation of this trend may be that magnesium hydroxide precipitated as the pH increased, thereby slowing the draining process.

The effects of lime on the fecal bacterial population during Run 2 are shown in Table 4. The table traces the fates of the fecal coliform and fecal streptocci organisms in the septage on the sand beds and in the underdrainage. Samples were taken every few days throughout the experimental

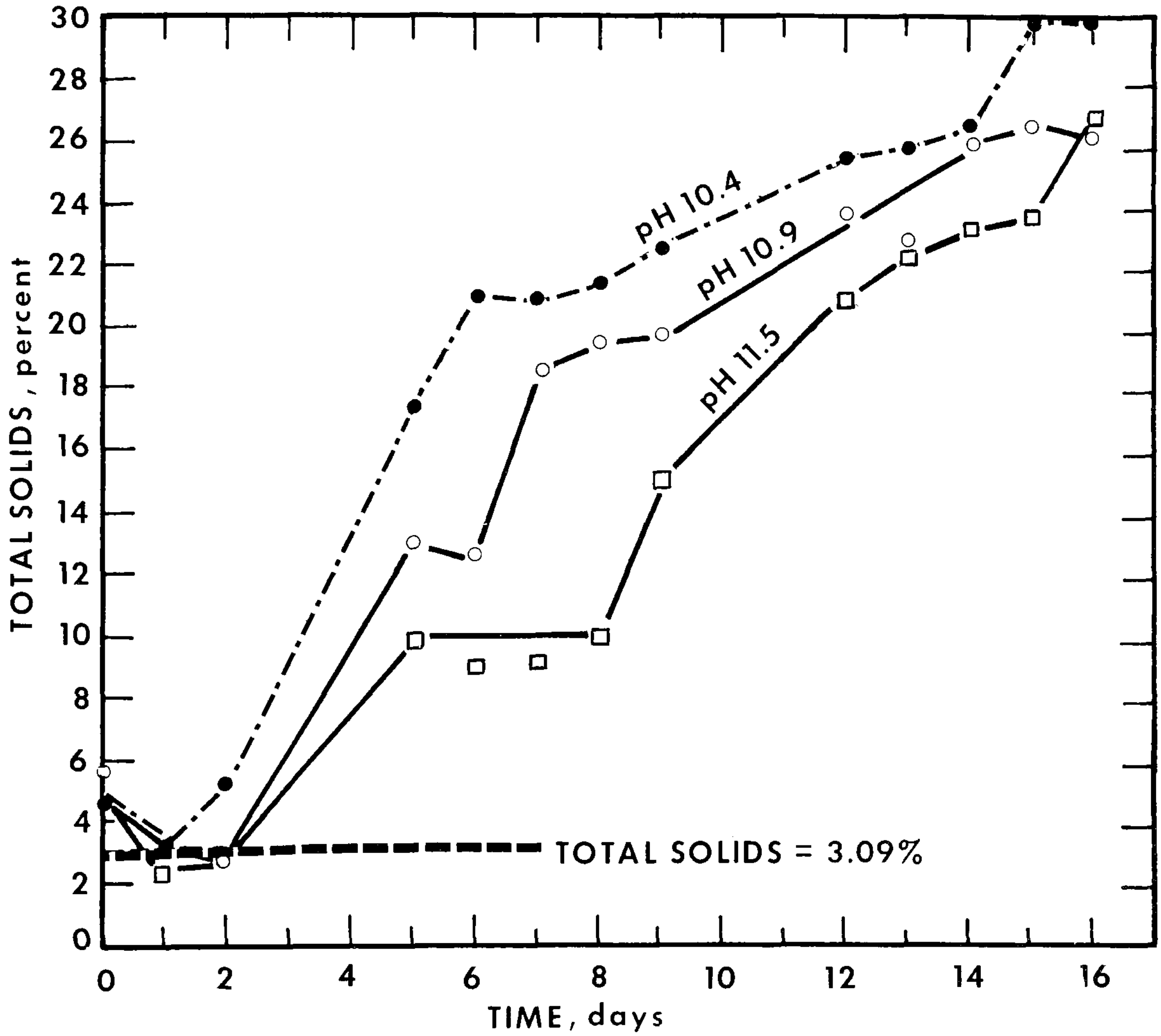

Figure 8.

SAND BED DEWATERING OF LIMED SEPTIC TANK WASTE - RUN 2
LEBANON, OHIO

Table 4.
BACTERIAL RESULTS - RUN 2

DAY	SEPTAGE PHASE	RAW	Septage HIGH LIME	Septage MEDIUM LIME	Septage LOW LIME	Underdrainage (counts/100 ml) HIGH LIME	Underdrainage (counts/100 ml) MEDIUM LIME	Underdrainage (counts/100 ml) LOW LIME
				Fecal Coliform Population				
0	Liquid*	1.7×10^6	$<5 \times 10^3$	$<5 \times 10^3$	$<5 \times 10^3$	1×10^5	2.5×10^5	600
1	Liquid		$<1 \times 10^3$	$<1 \times 10^3$	$<1 \times 10^3$	1.4×10^5	1.7×10^4	2.8×10^3
5	Solid**		<10	<50	<50	6×10^3	$<1 \times 10^3$	1.1×10^4
7	Solid		<10	<50	<50	$<1 \times 10^3$	$<1 \times 10^3$	$<1 \times 10^3$
12	Solid		<10	<50	<50	$<1 \times 10^3$	$<1 \times 10^3$	$<1 \times 10^3$
16	Solid		<10	<50	<10	1.2×10^3	<40	<40
				Fecal Streptococci Population				
0	Liquid	2.2×10^7	9.2×10^5	6.4×10^6	1.2×10^7	1.1×10^6	9.2×10^5	3.5×10^4
1	Liquid		1.5×10^6	8.8×10^6	1.4×10^7	1.8×10^6	3.8×10^5	6.2×10^5
5	Solid		2.9×10^4	1.0×10^4	3.0×10^5	4.2×10^5	3.3×10^6	5.7×10^5
7	Solid		1.6×10^5	5.6×10^5	2.8×10^6	1.5×10^6	8.5×10^5	3.5×10^4
12	Solid		5×10^3	4.1×10^5	1.2×10^5	1.4×10^3	3.4×10^4	2.0×10^3
16	Solid		2.65×10^3	1.2×10^6	1.5×10^6	400	3.0×10^3	720

* Liquid phase expressed as counts/100 ml

** Solid phase expressed as counts/gram

run. Fundamental considerations were (1) the amount of kill effected by the lime, (2) the quality of the material shoveled from the beds, (3) indications of regrowth, and (4) the quality of the underdrainage.

The fecal coliform count in the septage was reduced about 3 logs (≃99 percent) on contact with the lime for all pH levels. After 5 days, the septage was in the solid phase, and less than 50 counts per g were present in each batch. When the experimental run ended after 16 days, the fecal coliform population in the septage remained low, and no sign of regrowth appeared for any of the three lime concentrations. In some cases, the underdrainage initially contained high amounts of fecal coliforms, but after 7 days, relatively low levels were observed.

The fecal streptococci appeared to be more resistant to lime than the fecal coliforms, and the amount of resistance appeared to be related to the initial pH. About a 95-percent fecal streptococci reduction took place on contact with the lime at pH 11.5, about a 73-percent reduction at pH 10.9, and about a 45-percent reduction at pH 10.4. Even though 95 percent of the fecal streptococci population was reduced at the high lime dosage, it is important to note that a large number of organisms remained. By the 12th day of the run, the high-limed batch effected a 1-log indicator reduction from the first day in the solid phase versus no reduction for the medium- and low-limed batches. At the end of the run, the difference in qualities was even greater: signs of regrowth were present for the two lower dosages, but a further organism reduction was observed for the high dosage. The underdrainage contained high amounts of fecal streptococci for several days before a tailing-off occurred.

The pathogenic content of the waste was also monitored. No Salmonella species were detected in any of the raw or treated wastes or in the underdrainages. Pseudomonas aeruginosa was present in the unlimed waste in small numbers (3.6 counts per 100 ml), but did not appear in any of the limed wastes.

An attempt to determine the fate of the individual chemical constituents in the septage as it dried was made during Run 2. Points of interest were whether these materials would be located in the cake or in the underdrainage and what the effects of higher lime dosages would be. Results of this investigation appear in Table 5. All data related to the cakes are expressed on a weight-to-weight basis (mg of constituent per g of solids), and underdrainage data are expressed on a weight-to-volume basis (mg/l). The limed septage concentrations in Table 5 represent average daily values computed over the duration of the experimental run, whereas the underdrainage values are expressed as ranges. It should be further noted that the cake data were obtained by normalizing the daily total solids data and averaging the results. The following general conclusions can be drawn from the information presented: (1) the majority of the heavy metals remained with the cakes, (2) the high-limed cake (pH 11.5) retained slightly more of the heavy metals than the medium- (pH 10.9) and low-limed (pH 10.4) cakes, (3) nearly all of the organic content was found in the cake, and (4) the underdrainage contained much reduced amounts of chemical constitutents relative to those present in the raw waste. An encouraging

Table 5. Distribution of Chemical Constituents of Sand-Bed-Dried Limed Septage - Run 2

Concentration (mg/g solids)				Parameter	Concentration Range (mg/l)			
Limed Septage			Unlimed Septage		Unlimed Septage	Limed Septage Underdrains		
High	Medium	Low				High	Medium	Low
1327	1272	1288	1860	COD	57,000	224-1610	2030-3100	1080-2540
319	324	282	548	TOC	17,000	84-375	400-900	320-840
26	24	26	39	Total N (Org N, NH_3 NO_2, NO_3)	1,202	32-41	15-150	7-110
3.0	2.2	2.4	12	NH_3	380	15-24	18-91	8-73
12.6	10.8	10.8	7.2	Fe	222	4-10	4-67	1-62
7.0	6.3	6.8	6.8	Total P	210	1-3	1-7	2-8
1.2	1.02	0.92	1.06	Zn	33.0	0.1-1.2	0.8-1.9	0.5-1.0
0.13	0.08	0.10	0.30	Cu	8.8	0.1-0.3	0.2-0.5	0.1-0.14
0.36	0.29	0.33	0.21	Mn	6.5	0.9-1.2	0.2-2.4	0.9-1.9
0.047	0.034	0.036	0.045	Cr	1.4	0.0-0.1	0.1-0.2	0.0-0.1
0.037	0.028	0.030	0.022	Ni	0.7	0.1-0.2	0.1-0.2	0.1-0.3
0.013	0.011	0.009	0.006	Cd	0.2	0.06-0.1	0.06-0.1	0.06-0.1
0.36	0.29	0.33	0.21	Hg (μg/g)	6.5	0.9-1.2	0.2-2.4	0.9-1.9

fact was that despite pH decreases of daily monitored samples during the run, resolubilization of the metals did not occur. This suggests that the underdrainage from the sand beds at a conventional biological treatment plant can be recycled to the headworks of the plant with little additional metal contributions. The marked increase in iron levels of the limed septage was noted, but no explanation was apparent.

Results from Run 2 indicated that sand-bed dewatering of lime-treated septage is a potentially viable method of septage treatment that results in a good quality underdrainage amenable to conventional biological treatment.

Run 3 -- About 3,300 gal (12.5 m^3) of septage from two haulers were limed to pH 10.4, 11.0, and 11.5, and sand-bed dewatering studies were conducted for 5 days, the shortest duration of any of the experimental runs.

General and chemical characteristics of the septage as received appear as follows:

General:

Color		brownish-gray
pH		7.15
Total solids	%	4.08
Total volatile solids	%	71.2

Chemical:

	mg/l
COD	28,400
TOC	96,000
TKN	340
NH_3-N	89
Total P	77
Fe	600
Cu	23

Chemical -- continued

	mg/l
Ni	28
Zn	75
Cr	3.0
Cd	1.1
Mn	15
Hg	0.013

This batch of septage was different than any previously observed in that it possessed a fuel oil or gasoline odor and had a nearly neutral pH. The abnormally high TOC concentration probably reflected the fuel oil contribution to the waste. Also unique to Run 3 was that only about half of the lime requirement previously used was needed to stabilize the septage:

Actual pH	Gal (liters) of 25% lime slurry required	lb (kg) of lime required	lb of lime/ton (kg/metric ton) of dry solids
10.4	15 (57)	31.2 (14.2)	55 (28)
11.0	18 (68)	37.4 (17.0)	74 (37)
11.5	22 (83)	45.7 (20.7)	102 (53)

The pH trend witnessed during Runs 1 and 2 was once again evident during Run 3. The pH of the cakes in all sections decreased 0.5 to 1.0 pH units after the first day. The final pH of the 5-day run was 2.0 to 2.5 pH units units lower than the starting pH for each limed waste. The pH of the underdrainage from each bed ranged from 7.5 to 8.0, with minimal variance.

The dewatering trend for each bed appears in Figure 9. After 5 days, the septage on each of the beds thickened to greater than 32 percent. Unlike Run 2, there was no clear-cut relationship between the rate of dewatering and the lime dosage. A total volatile solids reduction from 71 to 41 percent took place during this run, probably because of the atypical organic nature of the waste.

The effects of lime on the fecal bacterial population for Run 3 are shown in Table 6.

Fecal coliform reduction of about 3 logs resulted when the septage was initially limed to pH 11.5 and 11.0, and 2 logs when limed to pH 10.4. Regrowth appeared to occur only in the cake originally limed to pH 10.4, and therefore the fecal coliform population of the low-limed cake was not stabilized by the end of the 6-day run. The underdrainage contained low populations of the indicator organism by the end of the run in each case, but the die-off was slower at the lower pH.

As in Run 2, the fecal streptococci were generally more resistant to lime than the fecal coliforms, and there was a relationship between initial lime dosage and the efficiency of kill. When the septage was limed to pH 11.5, 99 percent of the fecal streptococci population was destroyed; when limed to pH 11.0, 72 percent were killed; and when limed to pH 10.4, virtually no kill took place. By the end of the run, the number of counts per gram remaining in the high-limed cake was 1 to 3 logs fewer than the others. Whether or not regrowth occurred during the run was unclear. The underdrainage showed minimal reduction in fecal streptococci count by the end of the experimental run.

Results of the samples taken for pathogenic analyses were as follows: No <u>Salmonella</u> species were detected in any of the raw or treated wastes or in the underdrainages. <u>Pseudomonas</u> <u>aeruginosa</u> organisms were present in the unlimed waste in small numbers (7.3 counts/100 ml) but did not appear in any of the limed wastes.

Results from Run 3 indicated that sand-bed dewatering of limed septage can be accomplished in a few days under certain conditions. Also, bacterial reduction appeared to occur more consistently at pH 11.5 than at lower pH values, with fecal coliform removals being much greater than fecal streptococci removals.

<u>Run 4</u> -- Because the septage used during Run 3 was not of a purely domestic source, it was decided to conduct one more experimental run of varying lime dosages and a single application depth.

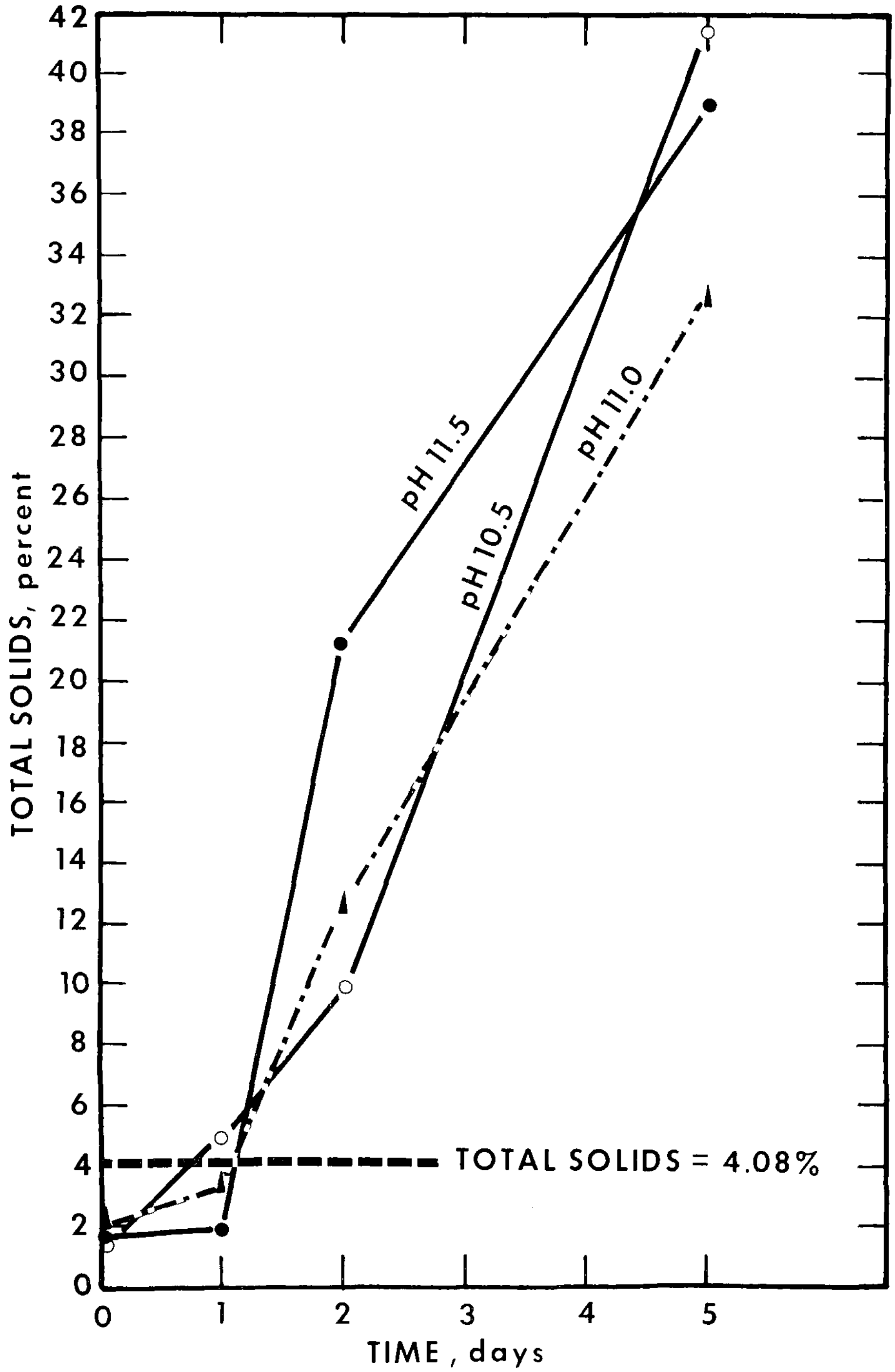

Figure 9. SAND BED DEWATERING TREND - RUN 3

Table 6.
BACTERIAL RESULTS - RUN 3

DAY	SEPTAGE PHASE	RAW	Septage: HIGH LIME	Septage: MEDIUM LIME	Septage: LOW LIME	Underdrainage (counts/100 ml): HIGH LIME	Underdrainage (counts/100 ml): MEDIUM LIME	Underdrainage (counts/100 ml): LOW LIME
				Fecal Coliform Population				
0	Liquid *	3.3×10^6	$<1 \times 10^3$	$<5 \times 10^3$	1×10^4	320	5.9×10^3	3×10^5
1	Liquid		$<1 \times 10^3$	$<1 \times 10^3$	3×10^4	–	– –	2.2×10^4
5	Solid**		<10	<10	1.5×10^3	<8	<40	1.76×10^3
6	Solid		—	—	—	16	<8	40
				Fecal Streptococci Population				
0	Liquid	3.0×10^6	2.5×10^4	8.5×10^5	1×10^7	2.3×10^4	2.0×10^5	2.8×10^5
1	Liquid		2.5×10^4	1.1×10^6	5.4×10^7	—	—	1.3×10^4
5	Solid		7×10^3	1.1×10^5	2.8×10^6	3×10^4	1.9×10^6	1×10^7
6	Solid		—			7.5×10^3	1.5×10^5	6×10^5

*Liquid phase expressed as counts/100 ml

**Solid phase expressed as counts/gram

Run 4 was conducted for 11 days. General and chemical characteristics of the of the unlimed septage as received appear below:

General:

Color		brown
pH		7.4
Total solids	%	4.5
Total volatile solids	%	76

Chemical:

	mg/l
COD	59,200
TOC	18,400
TKN	1,390
NH_3-N	212
Total P	29
Fe	370

Chemical -- continued

	mg/l
Cu	0.8
Ni	0.8
Zn	79
Cr	0.5
Cd	0.3
Mn	2.9

This batch contained a higher total and volatile solids content than any of the previous loads.

The septage was limed once again to pH 10.5, 11.0, and 11.5 and discharged to the respective sections of the covered bed. Lime requirements for Run 4 were the following:

Actual pH	Gal (liters) of 25% lime slurry required	lb (kg) of lime required	lb of lime/ton (kg/metric ton) of dry solids
10.4	14 (53)	29.0 (13.2)	82 (41)
10.95	16.5 (62)	34.2 (15.5)	115 (58)
11.5	18.5 (70)	38.4 (17.6)	163 (82)

Consistent with prior experimental runs, the pH of each limed waste decreased on the sand beds. A 0.5 to 1.0 pH drop was observed in each section after the first day. The final pH of the 11-day run was 2 to 3 pH units lower than the initial pH for each limed waste. The pH of the underdrainage from each bed remained essentially constant between 7.6 and 8.0.

The dewatering trend for each bed appears in Figure 10. The original waste contained almost 4.5 percent total solids. After 11 days, the septage on each of the beds thickened to at least 20 percent solids, and the run was ended. All septage was truckable at that point. The high-limed septage thickened in the shortest time and the low-limed material in the longest time. This order of thickening was the reverse of Run 2, showing that there was no consistent pattern to the rate of dewatering.

The effects of lime on the fecal bacterial population for Run 4 are shown in Table 7.

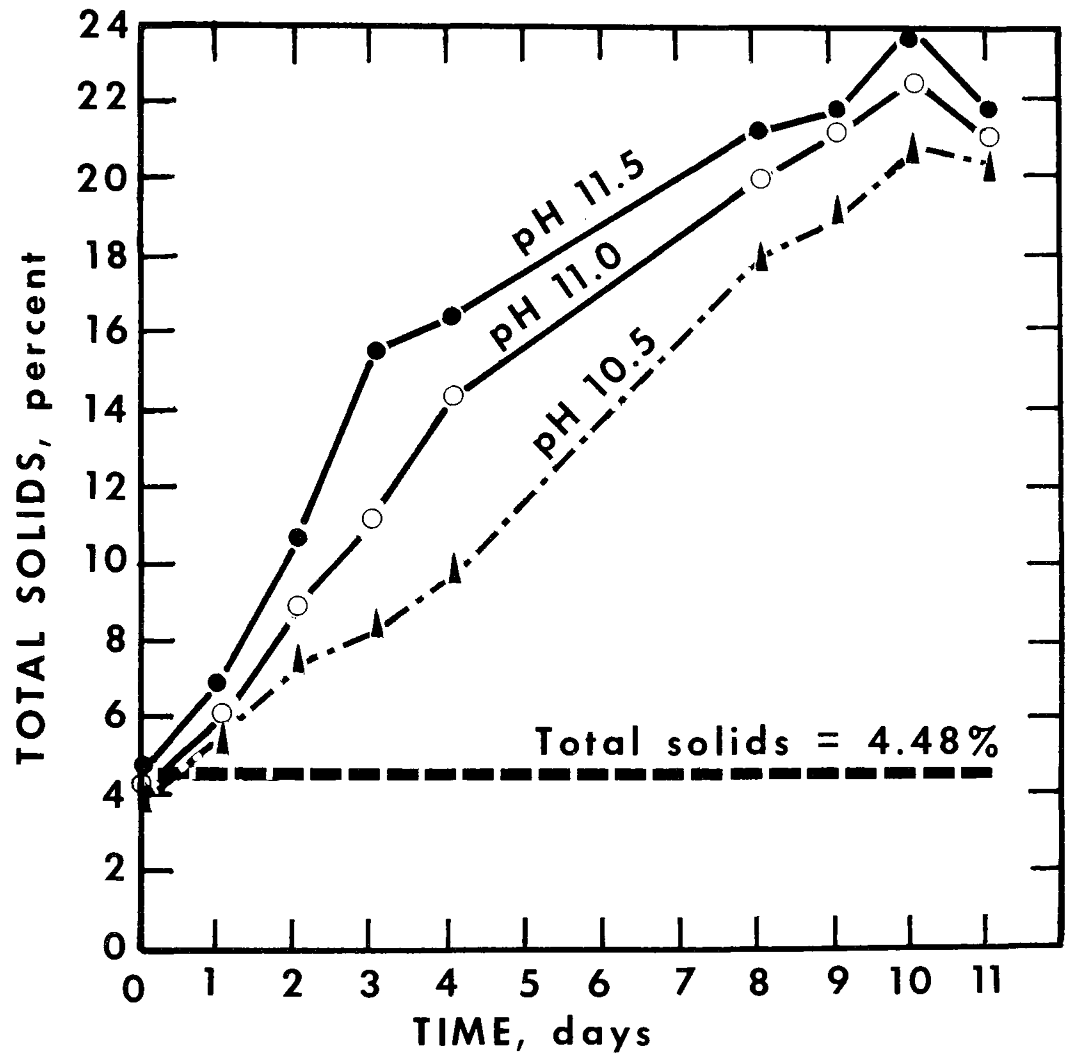

Figure 10. SAND BED DEWATERING TREND - RUN 4

Table 7.
BACTERIAL RESULTS - RUN 4

			Septage			Underdrainage (counts/100 ml)		
DAY	SEPTAGE PHASE	RAW	HIGH LIME	MEDIUM LIME	LOW LIME	HIGH LIME	MEDIUM LIME	LOW LIME
				Fecal Coliform Population				
0	Liquid*	1.1×10^6	$<1 \times 10^3$	$<1 \times 10^3$	1.2×10^4	1.08×10^3	2.2×10^4	3.9×10^4
1	Liquid		$<1 \times 10^3$	$<1 \times 10^3$	4×10^3	280	1.68×10^3	2.4×10^4
2	Liquid		$<1 \times 10^3$	$<1 \times 10^3$	2.5×10^4	64	360	1.2×10^3
8	Solid**		<10	1.15×10^3	750	<8	440	736
11	Solid		<10	350	10	464	128	88
				Fecal Streptococci Population				
0	Liquid	4.8×10^5	2×10^5	3.3×10^5	1.2×10^6	8.6×10^3	2.2×10^6	9.6×10^3
1	Liquid		1.8×10^5	1.6×10^5	7.5×10^5	3.5×10^5	6.3×10^5	1.4×10^4
2	Liquid		5×10^4	6×10^5	1.7×10^7	1.5×10^5	9.3×10^5	2.6×10^4
8	Solid		<50	<50	2.3×10^4	2×10^3	6.8×10^4	1.1×10^4
11	Solid		<50	350	4.8×10^5	3.3×10^5	2×10^4	4.2×10^3

*Liquid phase expressed as counts/100 ml

**Solid phase expressed as counts/gram

The previously observed trend for fecal coliform reduction was observed again during Run 4. Greater than 3 logs of kill took place on direct contact with the lime for the high- and medium-limed batches, and almost 2 logs for the low-limed batch. Regrowth appeared to occur for the septage initially limed to pH 10.4; it may have occurred for the medium-limed septage, and it did not occur for the high-limed septage. Underdrainage fecal coliform population initially decreased about 3 logs and remained low for the duration of the experimental run for the high-limed cake. The lower-limed batches showed initial underdrainage population reductions of approximately 1 log, with lower levels observed during the remainder of the run.

The initial resistance of fecal streptococci to lime was again observed during Run 4. About a 58-percent kill took place when the septage was limed to pH 11.5, about a 31-percent kill occurred when limed to pH 11.0, and no effect was observed at pH 10.5. By the end of the run, almost a 4-log difference existed in the number of organisms remaining in the cake between the high- and low-limed batches. Indications of regrowth appeared in the low-limed cake by the end of the experimental run, but the high-limed cake showed no such signs. Underdrainage levels were generally high in all cases.

Salmonella species were not found in any samples. *Pseudomonas aeruginosa* appeared in the raw waste at a concentration of 150 counts per 100 ml, but not in any of the limed septages. The underdrainage of the low-limed (pH 10.5) waste contained 150 counts per 100 ml the first day, but this figure was reduced to fewer than 3 counts per 100 ml by the second day.

A second attempt was made to follow the path of the chemical constituents as sand-bed dewatering was taking place. Table 8 shows the distribution of some of the monitored chemical constituents during Run 4. Results were similar to those obtained during Run 2, where it was observed that most of the materials remained in the cake and that the high-limed cake (pH 11.5) retained slightly more of the toxic metals than the lower-limed cakes.

Results from Run 4 supported earlier findings that dewatering of limed septage can take place in a few days with (1) good chemical capture and retention in the cake, (2) good fecal coliform reduction, and (3) rather good fecal streptococci reduction at high pH.

The four experimental runs brought to an end Phase I of the sand-bed dewatering study. Limed septage was shown to dewater to truckable levels in 5 to 16 days when 8-in. (20.3-cm) depths were applied. Each new load of septage was limed to pH 10.5, 11.0, and 11.5, resulting in average lime requirements of 90, 134, and 168 lb of lime per ton (45, 68, and 83 kg per metric ton) of dry solids, respectively. Fecal coliform reductions were consistently more effective at pH 11.5 than at lower pH values. Although fecal streptococci were more resistant to lime than the fecal coliforms, removals of these organisms were better at pH 11.5, and evidence of regrowth was least at the high pH. Chemical constituents were found

Table 8. Distribution of Chemical Constituents of Sand-Bed-Dried Limed Septage - Run 4

Concentration (mg/g solids)				Parameter	Concentration Range (mg/l)			
Limed Septage			Unlimed Septage		Unlimed Septage	Limed Septage Underdrains		
High	Medium	Low				High	Medium	Low
1518	1400	994	1320	COD	59,200	148-1710	455-2020	187-1110
291	272	268	408	TOC	18,400	40-700	128-680	84-340
6.4	4.0	3.3	8.2	Fe	370	0.3-4.2	0.6-3.2	0.4-6.0
1.7	1.4	1.2	1.75	Zn	79	0.1-0.4	0.1-1.0	0.1-2.0
0.066	0.064	0.054	0.064	Mn	2.9	0.3-0.5	0.1-0.5	0.8-1.3
0.016	0.005	0.006	0.016	Cu	0.8	0.1-0.2	0.1-0.2	0.1-0.2
0.016	0.012	0.010	0.016	Ni	0.8	0.1-0.2	0.1-0.2	0.1-0.4
0.010	0.011	0.012	0.011	Cr	0.5	0.1-1.0	0.1-0.2	0.1-0.4
0.006	0.008	0.004	0.007	Cd	0.3	0.1-0.2	0.1-0.2	0.1-0.2

mostly in the cake, and although a 0.5 to 3.5-pH-unit drop took place on the beds during any one run, resolubilization did not occur. COD/TOC ratios of the unlimed domestic septages for Runs 1, 2, and 4 were 3.7, 3.4, and 3.2, respectively.

Because of the relatively short dewatering times experienced during Phase II, bed depths greater than 8 in. (20.3 cm) were felt to be worthy of evaluation. For this reason, two more experimental runs were initiated. The purpose was to examine the performance of high-limed septage on sand beds at application depths up to 24 in. (60.9 cm). At the same time, greater effort was to be devoted to conducting material balances on the system.

Experimental Runs 5 and 6: Application

Run 5 -- Domestic septage was limed to pH 12.3 in the holding tank and discharged to the experimental sand beds. Application depths of 8 in. (20.3 cm), 16 in. (40.6 cm), and 24 in. (60.9 cm) were applied to the beds and to the drums used to collect underdrainage. General and chemical characteristics of the unlimed septic tank waste are shown below:

General:

pH		7.3
Total solids	%	4.6
Total volatile solids	%	59.0

Chemical:

	mg/l
COD	68,490
TOC	18,000
TKN	1,560
NH_3-N	182
NO_3-N	0.1

Chemical -- continued

	mg/l
Total P	291
Fe	590
Cu	0.3
Zn	120
Mn	9.0

The dewatering pattern for each loading appears in Figure 11. If 23 percent total solids concentration were considered an attainable point to truck the waste, the following drying times would be required: 6 days (8-in. or 20.3-cm depth), 13 days (16-in. or 40.6-cm depth), and 20 days (24-in. or 60.9-cm depth). Although the 24-in. application batch thickened to almost 24 percent, the consistency of the cake was of a nonuniform nature. Much of the cake was water-bound, even after 35 days on the bed. The difficulties in sampling such a mixture were evident from the apparent decrease in solids concentration during the first 3 days of the run. Considerable amounts of green algae were present by the end of the experimental run for the 24-in. (60.9-cm) batch, and many flies were noted.

The pH drop after the first day was 0.1 to 0.2 pH units, as compared to 0.5 to 1.0 pH units during the previous experimental runs. This difference may be explained by the higher initial pH during Run 5. An interesting note is that the pH decrease was less rapid with the greater application depths. For example, pH 9.4 was reached after 9 days in the 8-in. (20.3-cm) bed, whereas pH 10.0 was reached after 21 days in the

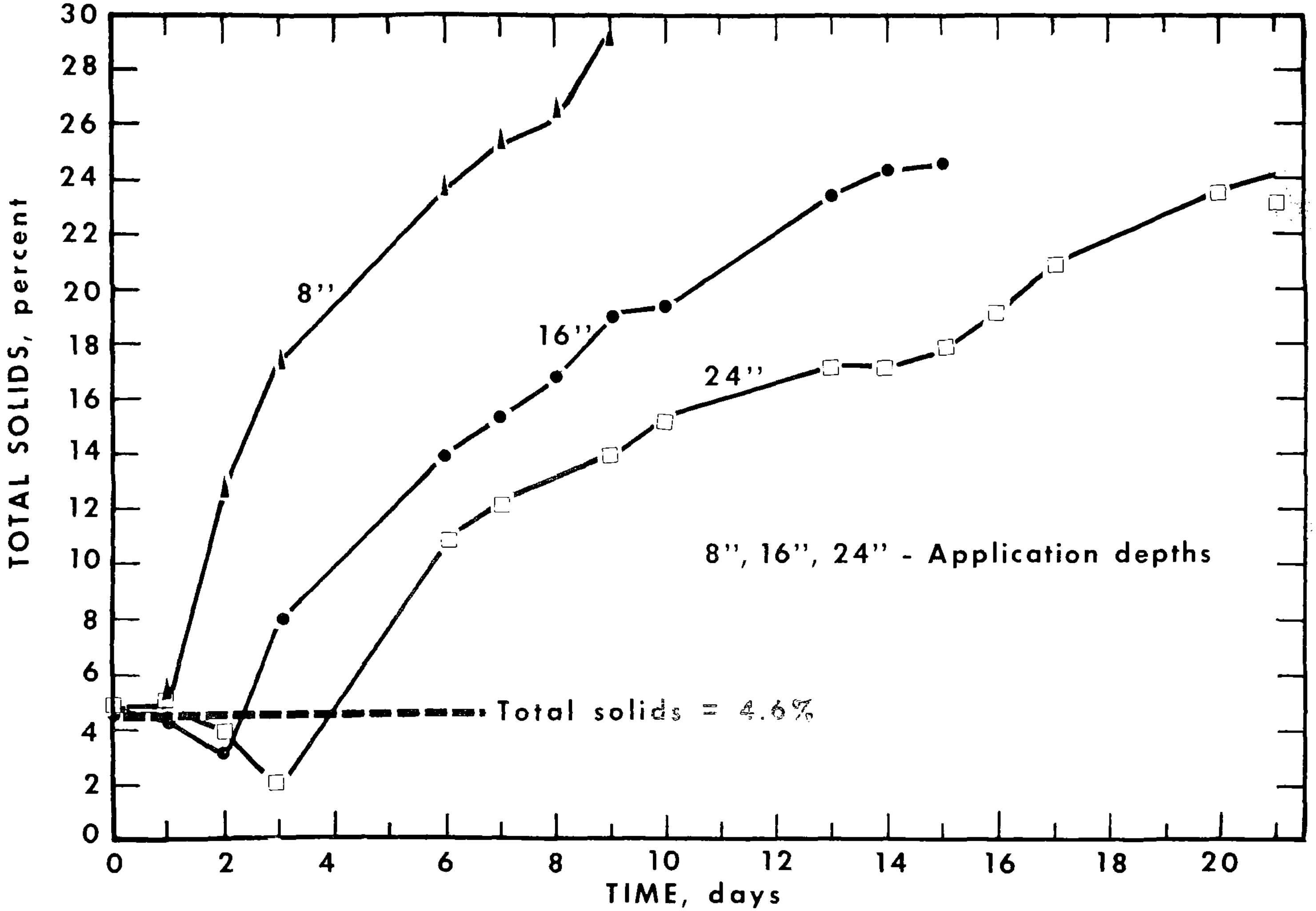

Figure 11. SAND BED DEWATERING OF LIMED (pH 11.5) SEPTIC TANK WASTE - RUN 5
LEBANON, OHIO

24-in. (60.9-cm) bed. This result indicates that the longer the septage remained liquid, the more gradual the pH loss was. Measurements of pH became more difficult as the septage approached the solid phase. Underdrainage pH remained constant at pH 7.4 in all cases.

The nature and volume of bed underdrainage from the three fiberglass drums was closely monitored during Run 5. The results of the volume determinations appear in Figure 12. For the shallowest application depth, increasing breakthrough was observed for the first 2 days, after which decreasing volumes were collected until the eighth day, when virtually no more underdrainage was present. For the 16-in. (40.6-cm) depth of applied waste, underdrainage volume increased until the third day and then gradually decreased to almost zero on the tenth day. The deepest (24-in. or 60.9-cm) septage application produced increasing underdrainage volumes until the fifth day. About 75 percent of the total underdrainage from both the 8-in. (20.3-cm) and 16-in. (40.6-cm) batches of septage was collected within the initial 3 days of the experimental run. About 9 days were required to collect a comparable percentage for the 24-in. (60.9-cm) batch. Evaporation and sand-bed retention took place and accounted for a 40-percent volume loss at 16- and 24-in. (40.6- and 60.9-cm) depths and a 50-percent volume loss at the 8-in. (20.3-cm) depth when average bed temperature was 28°C and average relative humidity was 80-percent. The importance of these two variables has been emphasized in the literature.[16]

An additional purpose for the use of the drums during Run 5 was to determine the fate of chemical constituents in the septage after their application onto the sand beds. The results are summarized in Table 9. Daily measurements of underdrainage concentration and volume were made; total mass for each constituent leaving the drum was computed and compared to the mass initially applied to the drum. Table 9 indicates that in all cases, the major portion of the organics (COD and TOC), heavy metals, and phosphorus remained in the cake. Iron and zinc were complexed most effectively. Copper and manganese were better retained in the cake at the 8-in. (20.3-cm) depth than at the greater depths. Even though a 2- to 3-pH-unit decrease occurred during the run, the phosphorus content of the septage remained in the cake, with very little lost to the underdrainage.

Some nitrification took place through the sand in all cases. The increase in ammonia levels present during the 16-in. (40.6-cm) and 24-in. (60.9-cm) applications were probably due to hydrolysis of organic nitrogen.

Although the domestic septage was limed to pH 12.3 instead of pH 11.5, no additional bacterial removals occurred in either the cake or the underdrainage. The pathogens *Salmonella* species and *Pseudomonas aeruginosa* were present in higher numbers (>1100 counts per 100 ml each) in the raw septage than previously observed, but the amounts were reduced to <3 counts per 100 ml upon contact with the lime. Some indications of *Pseudomonas* regrowth appeared in the underdrainage.

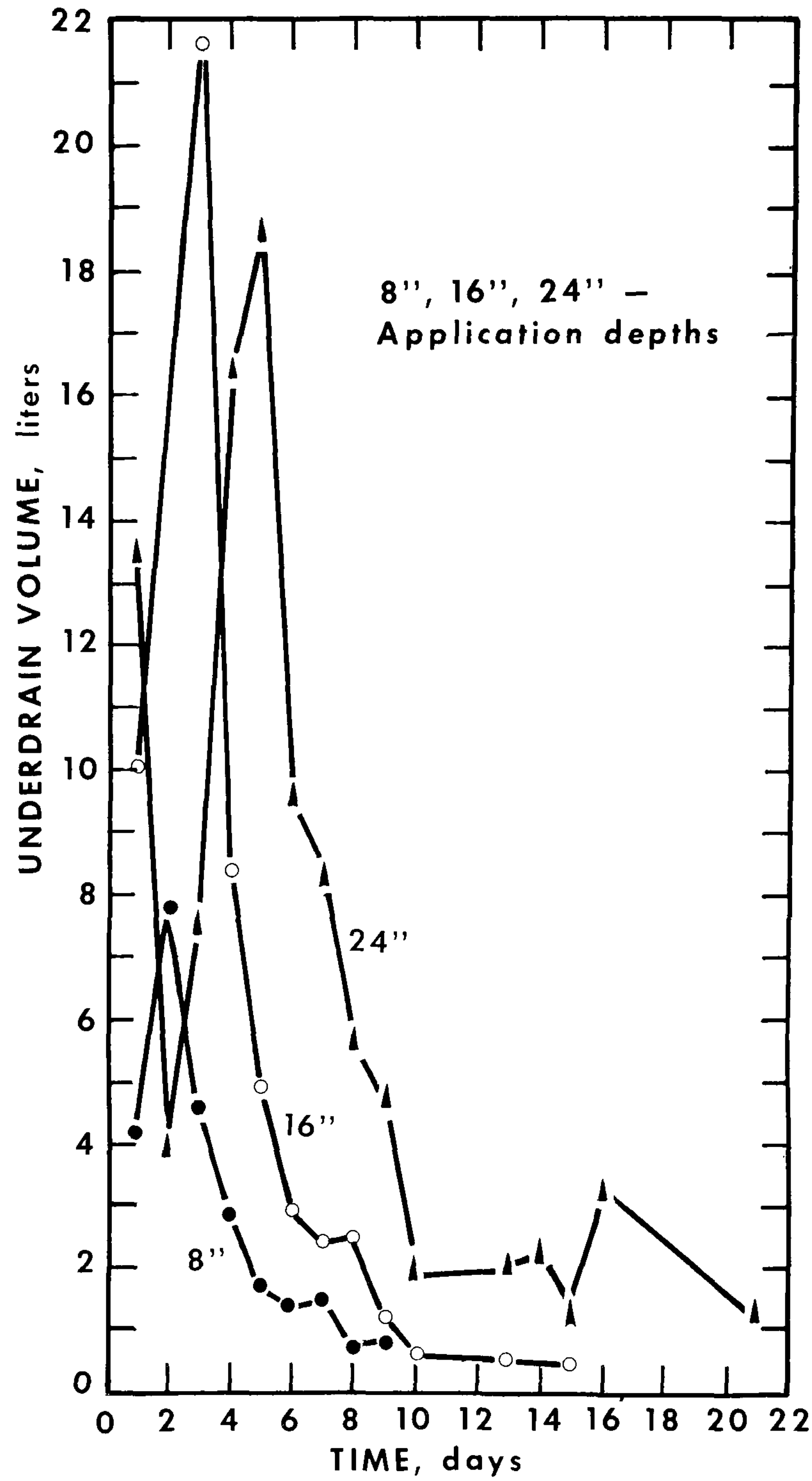

Figure 12. UNDERDRAINAGE BREAKTHROUGH - RUN 5

Table 9.

CHEMICAL MASS BALANCE - RUN 5

INCHES OF SEPTAGE APPLICATION (cm) / PARAMETER	8 (20.3)		16 (40.6)		24 (60.9)	
	APPLIED *	UNDER-DRAINAGE*	APPLIED*	UNDER-DRAINAGE*	APPLIED*	UNDER-DRAINAGE*
TKN	72	1.71	144	13.1	216	22.2
NH_3-N	4.2	1.16	8.4	10.6	12.4	18.6
NO_3-N	0.006	2.21	0.012	1.4	0.018	2.3
Tot. P	16.3	0.117	32.6	0.055	48.9	0.092
COD	3820	20.7	7640	172	11,460	299
TOC	832	6.0	1664	65	2,496	110
Fe	25.6	0.014	51.2	0.124	76.8	0.147
Cu	0.033	0.006	0.066	0.030	0.099	0.032
Zn	6.2	0.004	12.4	0.016	18.6	0.050
Mn	0.417	0.035	0.834	0.142	1.25	0.284

*Total mass (grams)

Results from Run 5 indicated that sand bed applications of limed septage might be successfully made at depths greater than 8-in. (20.3-cm) but probably less than 16-in. (40.6-cm) in the covered sand-bed environment. Satisfactory dewatering was obtained in a reasonable period of time, and most of the underdrainage was collected during the initial 3 days of the run for these two application depths. A chemical mass balance around the drum verified that most of the organics and inorganics remained with the limed cake, even under conditions of decreasing pH. Evidence of nitrification through the sand beds was also observed.

Run 6 -- A final experimental run was made to better quantify the loading limits of septage discharges onto sand beds and to obtain additional data on underdrainage characteristics.

Almost 2,500 gal (9.5 m^3) of domestic septage was limed to pH 11.5, and the required amounts were discharged to the sand beds and the underdrainage collection drums. Application depths of 8-in. (20.3-cm), 12-in. (30.5-cm), and 16-in. (40.6-cm) were examined. The chemical and general composition of the trucked waste are shown below:

General:

Color		brown
pH		6.9
Total solids	%	4.01
Total volatile solids	%	74.0

Chemical:

	mg/l
COD	53,600
TKN	1,140
NH_3-N	48
NO_3-N	0.3

Chemical -- continued

	mg/l
Total P	164
Fe	250
Cu	0.85
Zn	58
Mn	2.4

The dewatering trend for Run 6 is shown in Figure 13. Total solids levels of 20-percent were obtained after 5 days (8-in. or 20.3-cm depth), 12 days (12-in. or 30.5-cm depth), and 17 days (16-in. or 40.6-cm depth). Once again, the rate of dewatering was very much a function of the amount of septage initially applied. Note that although the solids concentration of the thickest batch eventually reached a truckable consistency, the process was relatively slow and the mixture less homogenous than the others. The 8-in. (20.3-cm) application also appeared to be more effective than the 12-in. (30.5-cm) application; but the use of an intermediate application may have been optimum. A major consideration, of course, is the frequency of bed cleaning; application of incremental batches at various times may be more desirable than only one loading.

Underdrainage volume was monitored for Run 6 in the same manner as for Run 5, and the results appear in Figure 14. As was the case previously, increasing liquid breakthrough occurred for about 3 days, followed by very little drainage for the remainder of the run. The dashed lines on the down side of each curve in Figure 14 indicate that more than one day was

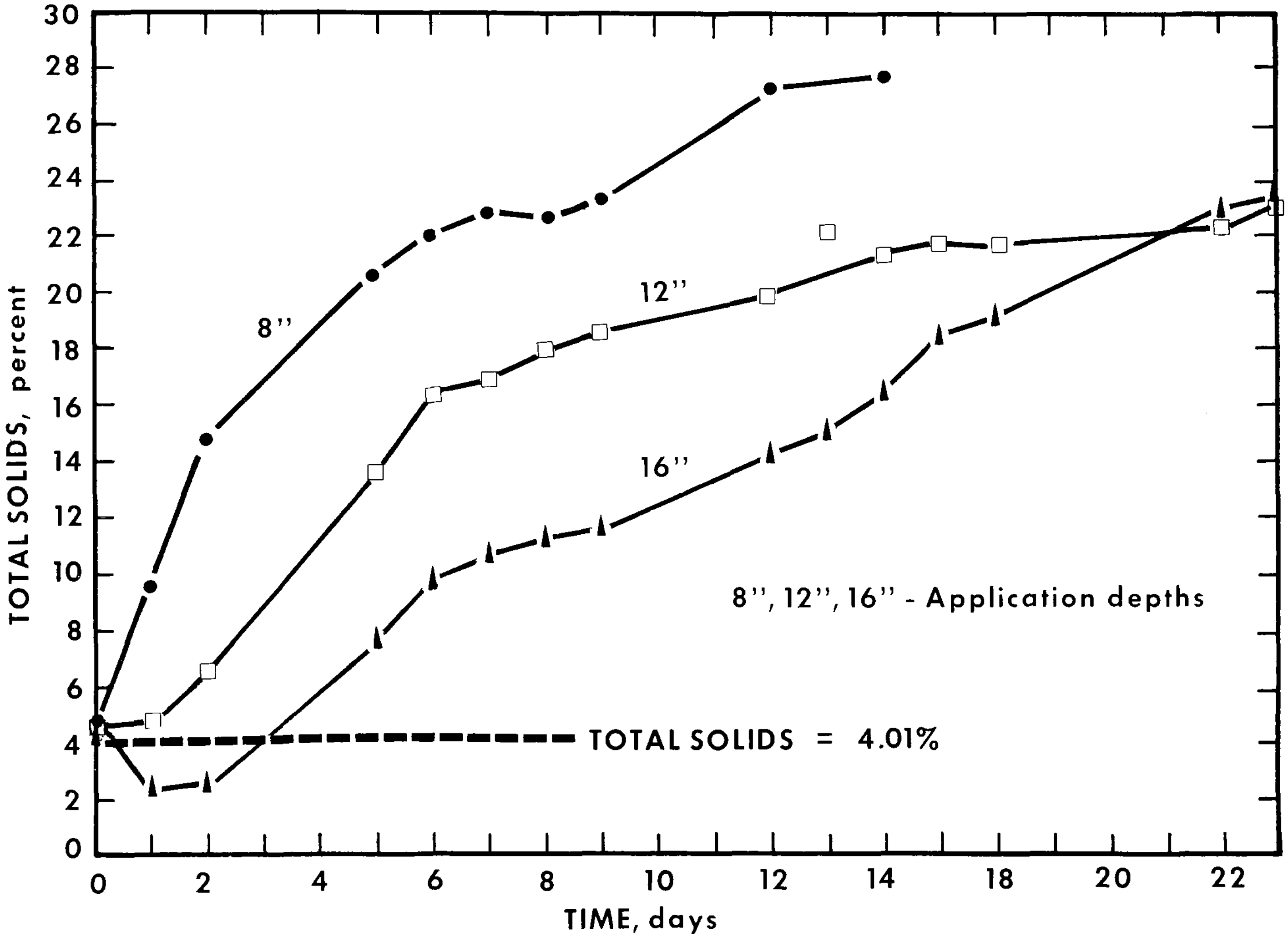

Figure 13. SAND BED DEWATERING TREND - RUN 6

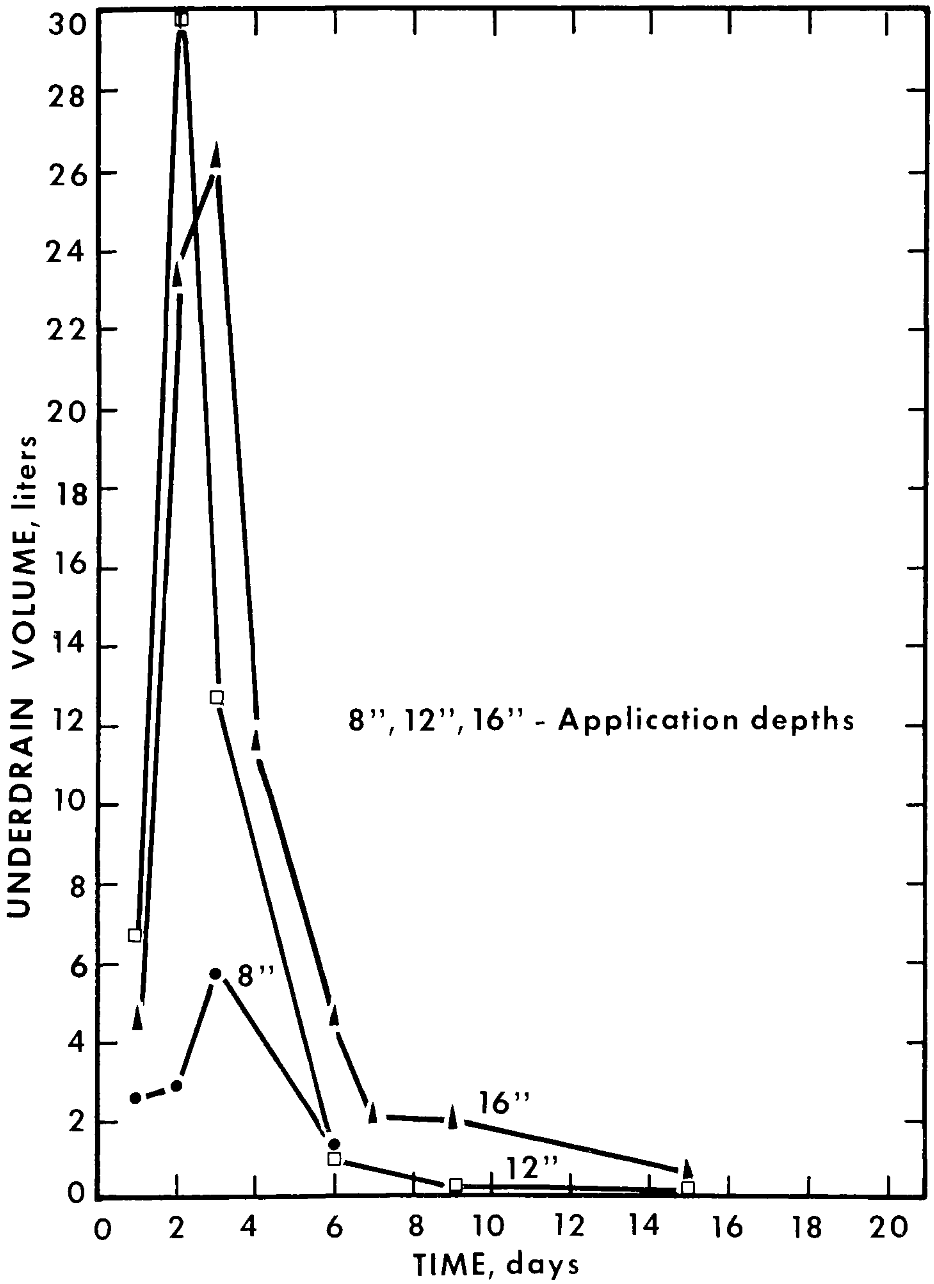

Figure 14. UNDERDRAINAGE BREAKTHROUGH - RUN 6

necessary to accumulate measurable volumes. Greater than 75-percent of the total underdrainage was collected within the first 3 days for the 8-in. (20.3-cm) and 12-in. (30.5-cm) applications and within the first 4 days for the 16-in. (40.6-cm) application. Evaporation and sand-bed retention once again accounted for significant volume losses and seemed to be related to the depth of applied septage. Volume losses varied from 75-percent for the 8-in. (20.3-cm) application, to 39.5-percent for the 12-in. (30.5-cm) application, to 34.6-percent for the 16-in. (40.6-cm) application at an average sand-bed temperature of 21°C and an average relative humidity of 70-percent.

Underdrainage characteristics were monitored as in Run 5. The results appear in Table 10. Again, the great majority of pollutants was present in the cake for each application. Similar trends to those experienced during the previous run were observed for the fate of the heavy metals: iron and zinc were better held in the cake than copper and manganese, both of which were not appreciably retained in the 12-in. (30.5-cm) and 16-in. (40.6-cm) limed cakes. The phosphorus and organic contents of the septage remained in the cake and were not lost to the underdrainage during the run. Some nitrification through the sand beds also took place in Run 6, although the amount was negligible for the 16-in. (40.6-cm) depth.

Results from Run 6 confirmed much of the data obtained during Run 5. They showed that lime-treated septage could be applied to sand beds at a depth of 8 to 12-in. (20.3 to 30.5-cm), and that a truckable stage would be reached between 6 and 13 days. Most of the septage chemical pollutants remained in the cake throughout the experimental run. Most of the underdrainage was collected in the first few days, and in most cases, it contained relatively small amounts of organics and inorganics.

The study was ended after Run 6, but the sludges were allowed to remain on the sand beds for several weeks following. No further monitoring was made, but it was noted that (1) the cakes became detached from the sand (i.e., they could be lifted off in sheets), and (2) no obnoxious odors occurred.

Table 10.
CHEMICAL MASS BALANCE - RUN 6

INCHES OF SEPTAGE APPLICATION (cm) / PARAMETER	8 (20.3)		12 (30.5)		16 (40.6)	
	APPLIED*	UNDER-DRAINAGE*	APPLIED*	UNDER-DRAINAGE*	APPLIED*	UNDER-DRAINAGE*
TKN	59	0.75	88.2	8.52	118	14.3
NH_3 - N	8.75	0.30	13.1	7.06	17.5	12.7
NO_3 - N	0.012	2.02	0.018	2.91	0.024	0.026
Tot. P	10.8	0.005	17.2	0.031	21.6	0.050
COD	3040	7.0	4560	106	6080	162
Fe	8.9	0.028	13.4	0.159	17.8	0.341
Cu	0.018	0.002	0.027	0.017	0.036	0.014
Zn	2.02	0.002	3.04	0.013	4.04	0.020
Mn	0.131	0.026	0.196	0.128	0.262	0.198

*Total mass (grams)

COST ANALYSIS

A cost estimate for the treatment of septage at small treatment plants via the lime stabilization/sand-bed dewatering approach was made.[17] The use of covered sand drying beds was considered in the analysis. The following assumptions have been made:

1. The average septic tank is pumped every 3 years and is of a 1000-gal (3.8 m^3) capacity.
2. Each week day, 5,000 gal (19.0 m^3) of septage is treated.
3. The average total solids content of the unlimed septage is 4.0 percent and requires 200 lb lime per ton dry solids (100 kg per metric ton) to raise the pH to 11.5.
4. The average drying time for each 5,000-gal (19.0 m^3) limed batch is 7 days based on an 8-in. (20.3-cm) applied depth.
5. Diffused air requirements to mix the septage and lime in the holding tank is about 100 cfm per 1000 ft^3., or 67 cfm based on 5,000 gal (19.0 m^3).
6. A front-end loader would clear one bed after 7 days, the next bed after 8 days, etc.
7. Labor is to be provided by sewage treatment plant personnel and would require one man for 2 hr each day, or 10 man-hr per week, to prepare and apply 25,000 gal (95.0 m^3) per week to the beds.

Based on these assumptions, the following costs were computed:

Capital Costs:

Sand bed, 6,000-sq-ft (540 m^2)	$ 20,300
Bed cover @ $20/sq-ft ($220/m^2)	$120,000
Holding tank, 6,000-gal (22.8 m^3), steel	$ 2,100
Lime feeder and slurry mixer	$ 2,100
Lime storage and handling building	$ 20,000
Diffused air system, 67 cfm, or 100 cfm per 1000 ft^3	$ 6,000
Yardwork	$ 26,700
Front-end loader	$ 11,000
Land (estimate 3 acres @ $1,000)	$ 3,000
Total construction cost	$211,200

Capital Costs -- continued

Engineering, legal, fiscal and administrative cost (22% of construction cost)		$ 46,464
Subtotal		$257,654
Interest during construction		$ 7,000
Initial investment cost		$264,664
Amortization (excluding land), 6%-25 yr		$21,705/yr
Operation and maintenance costs:		
Labor requirements:		
Lime handling and mixing	man-hr/yr	360
Sludge application	man-hr/yr	520
Sludge removal and hauling	man-hr/yr	230
Bed maintenance	man-hr/yr	330
Diffused air system	man-hr/yr	200
Total [Payroll Man-Hours]	man-hr/yr	1,640
Labor costs:		
Direct labor cost @ $4.70/hr		$ 7,710
Indirect labor cost, 15% of above		$ 1,160
Total labor cost/yr		$ 8,870
Materials and supplies cost/yr:		
Lime @ $4/cwt		$ 350
Electric power @ 2¢/kwh		$ 410
Maintenance materials		$ 3,420
Total materials and supplies		$ 4,180
Amortization/yr		$21,705
Total operation and maintenance cost/yr.		$34,755
Households served/day		5
Total households served (assuming pumping every 3 yr)		3,900
Cost/yr/household		$8.91

Note that more than 40-percent of the initial investment cost is contributed by the purchase of the drying bed cover. Therefore, if open beds are used, the annual cost per household would be considerably less than $8.91.

The cost of this septage treatment process appears to be competitive with sludge handling costs at small activated sludge plants. For plants of the 1-mgd (3785-m^3 per day) size, such costs vary between approximately $145 per dry ton($0.160 per dry kg) [for gravity thickening, anaerobic digestion, and drying beds] and $360 per dry ton ($0.397 per dry kg) [for gravity thickening, anaerobic digestion, sludge holding tanks, vacuum filtration, and incineration]. Based on a total solids concentration of 4 percent, the estimated cost of treatment by sand-bed dewatering of lime-treated septage is $176 per dry ton ($0.194 per dry kg).

CONCLUSIONS

1. Septic tank pumpouts are highly variable in their physical, chemical, and biological characteristics.
2. The frequency of septage discharges to the treatment plant was greatest during the summer months.
3. The septage contained high metal concentrations, and therefore any effective treatment method must consider proper disposal of these materials.
4. Poor settling characteristics were exhibited by the septage, even after coagulant and polymer additions; therefore, separate treatment of supernatant and sediment was not possible.
5. Results from this study have shown that lime stabilization of the septage followed by sand-bed dewatering is a potentially feasible method of septage treatment.
    a) A holding tank equipped with air diffusers adequately mixed the lime with the septage with little odor generation.
    b) To achieve effective fecal coliform reduction, the septage must be limed to a minimum pH of 11.5. Although fecal streptococci were more resistant to lime than fecal coliforms, removals of these organisms were also best at pH 11.5, and evidence of regrowth was least at the high pH.
    c) The pathogenic <u>Salmonella</u> species and <u>Pseudomonas aeruginosa</u> in raw septage were destroyed by lime addition.
    d) Septage applications of 8-in. (20.3-cm) on covered sand drying beds can be made to achieve truckable cakes (20 to 25 percent total solids concentrations) in less than 1 week in most cases.
    e) Almost all of the organics and toxic metals were complexed in the cake at pH 11.5; the underdrainage from the sand beds generally contained low amounts of chemical pollutants.
    f) The lime stabilization approach resulted in little volatile solids reduction.
    g) Average lime requirements to raise the septage to pH 11.5 were 168 lb per ton of dry solids (83 kg/metric ton).
    h) Some nitrification took place through the sand beds.
    i) Most of the underdrainage was collected in the first 3 to 4 days after application on the sand beds.

j) Evaporation and sand-bed liquid retention contributed 35 to 75 percent of the underdrainage volume losses and was inversely related to the application depth.

k) The economics of the process appear to be competitive with those of sludge handling at 1-mgd (3785-m^3 per day) activated sludge plants.

RECOMMENDATIONS

Though the results of this study have indicated that lime stabilization followed by covered sand-bed dewatering offers a technically feasible and cost-effective method of treatment for septic tank sludges, other methods should also be evaluated. These methods include aerobic or anaerobic digestion (either separately or in conjunction with treatment plant sludges), or the commercially available Purifax system. In some instances it may be feasible to hold intermittent septage discharges for continuous blending with sewage treatment plant influent at rates that minimize plant upset.

Additional research that is necessary to better define the lime stabilization/sand-bed dewatering concept includes:

(1) Examination of the performance of lime-stabilized septage on uncovered sand beds over a variety of seasonal conditions to determine:

- a) typical drying rates to be expected;
- b) the effect of prolonged drying times and intermittent wetting on the cake, on the underdrainage quality, and on the re-emergence of pathogens, pathogenic indicator organisms, and odors; and
- c) the long-term fate of cakes in landfill sites.

(2) Evaluation of the impact of underdrainage return on a sewage treatment plant.

(3) Examination of the feasibility of land-spreading of limed septage as a liquid and as a cake.

(4) Determination of the fate of viruses in the lime stabilization of septage.

(5) Investigation of intermediate applications between 8-in. (20.3-cm) and 12-in. (30.5-cm).

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15. SUPPLEMENTARY NOTES

16. ABSTRACT

Approximately 5 billion gal (18,927,000 m^3) of septage must be annually disposed of in the United States, a volume that is nearly equal to that of undigested raw and secondary municipal sludges. Few desirable methods exist for disposing of the sludge that is periodically pumped from septic tanks. This report describes the results obtained from a pilot study of one alternative septage treatment method-lime stabilization followed by covered sand-bed dewatering.

The study was conducted in two phases. Phase I (4 months) consisted of the general, chemical, and biological characterizations of the incoming septage. Attempts were made to thicken the material via stirring, polyelectrolyte addition, and lime addition. Phase II (9 months) concerned itself with the application of lime septage onto covered sand beds. Four experimental runs were conducted to assess the feasibility of such an approach. The septage was limed to pH 10.5, 11.0, and 11.5 and applied at 8-in (20.3-cm) depths. Underdrainage and cake characteristics were monitored and practical sand-bed application rates were determined. A materials balance of chemical constituents around the system was made.

A cost estimate for the treatment of septage at small treatment plants via this method is included.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
*Septic tanks Sludge disposal	Sand bed dewatering Septage Lime stabilization	13B

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